Popular Astronomy.

Vol. VI. No. 10. DECEMBER, 1898. Whole No. 60.

THE SUN DIAL OF AHAZ.

J. MORRISON, M.D., M.A., PH.D.*

FOR POPULAR ASTRONOMY.

Time like space cannot be defined; we conceive it to be unlimited, continuous, homogeneous and divisible without end, but these characteristics convey to us no idea of its nature or essence. It is, however, unlike time in that it has only one dimension. As regards continuous duration we can only look backward to the past and forwards to the future. It can therefore be represented graphically by a straight line extending in opposite directions to infinity.

Space on the other hand has three dimensions, length, breadth and depth or height, each extending in opposite directions to infinity. Plane or Euclidean geometry makes us acquainted with the properties of space of one and two, and solid geometry with those of three dimensions; and notwithstanding its apparent impossibility, there may be a fourth dimension, or what is equivalent thereto, of which we have not and can not have, from our present standpoint, any consciousness while in our present state of existence.

In the future life we may possibly live in four dimensional or hyperspace, but however this may be, we are certain of one thing, viz.: we shall exist independently of matter and probably also of time and space as we now understand them. The discussion of these quantities in the abstract involves the consideration of the infinite, which our finite minds cannot grasp and about which we cannot reason intelligently.

The determination of a scientific unit for the measurement of time, has been not only a very difficult problem but one which has required centuries for its solution. With space it is quite otherwise, for we can apply an arbitrary unit such as a yard measure as often as necessary to find how many yards a given length contains. Our unit too will remain invariable while the temperature is constant. In the case of time however we can

* Mem. Coll. of Physicians and Surgeons, Ont. Hon. Mem. Astronomical and Physical Society of Toronto.

not keep such a measure by us, nor can we repeat the measurement over and over again because time once passed is irretrievably lost forever. Neither will an appeal to our senses justify any result of our measurements. The recurrence of certain astronomical phenomena first furnished man with the natural units of time; thus, the Sun in his annual and diurnal motions marked out times and seasons, days and years, but it was by no means an easy matter to determine their precise beginning and ending. The subsequent artificial subdivisions of the day into hours, minutes and seconds is of great antiquity and is due to the Chaldeans. It was soon discovered that the vear and day are not of constant length and that the interval from noon to noon varied from day to day. The only invariable unit of time we have is furnished by the diurnal motion of the Earth; the time it takes to turn once on its axis or through 360° is assumed to be always the same and is called a sidereal day, hence in 1 hour it turns through 15°, in one minute 15′ and so on. We are however by no means certain that this unit is absolutely invariable. Geodetic measurements have shown that the Earth is not exactly an oblate spheroid of revolution, nor does it appear that the density is the same at equal depths, from which circumstances it may result that the axis of revolution does not coincide with the geometric axis. These, combined with the increase of mass due to the fall of meteoric matter together with tidal friction, may and probably do cause the length of the sidereal day to vary, and there is good reason to believe that it is now about $\frac{1}{6}\frac{1}{0}$ of a second longer than when the Egyptians were laying the foundations of their loftiest pyramid.

The sidereal day can only be determined by refined astronomical observations and is therefore not a suitable unit for the ordinary purposes of civil life. The apparent or true solar day is the time the Earth makes one revolution in regard to the Sun and it is apparent or true noon when the Sun is on the meridian. Owing to the motion of the Earth in its orbit or to the apparent motion of the Sun eastward, the true or apparent solar day is about four minutes longer than the sidereal. The apparent solar days are unequal and the mean or average of them all during a year is called a mean solar day which is also divided in hours, minutes and seconds, and these are now the units employed in the ordinary affairs of life in all civilized countries.

Mean time is comparatively a recent invention and was not introduced into France until the year 1816.

Formerly there was no common agreement as to when the day

began. In all civilized countries, the day is now regarded as beginning at midnight, as was first suggested by Hipparchus.

Ptolemy and the ancient Egyptians counted the 24 hours from noon and this practice is still followed by astronomers. There is also other ancient authority for the same method, thus we read in Genesis "The evening and the morning were the first day," and so on, from which language we infer that the day was regarded as beginning at noon.

The earliest devices for subdividing the day into hours, of which we have any positive knowledge, were the gnomons or styles employed in Ancient Egypt and Asia Minor. These consisted at first of a vertical pillar or style erected at the centre of a series of concentric circles described on a horizontal plane and located at such distances from each other that the extremity of the shadow of the pillar or style passed from one to another during approximately equal intervals of time. Of course such a device could be accurate only on certain days of the year. It was only an approximation and a rough one at that.

Subsequently the style or gnomon was inclined or directed to the pole about which, it was observed, all the heavenly bodies appeared to revolve. In order to give it stability, it was made in the form of a right-angled triangle whose plane coincided with the meridian and whose hypothenuse had an elevation above the horizontal plane equal to the latitude of the place. Such an instrument when accurately constructed and correctly adjusted, is capable of indicating true or apparent time throughout the entire year. Owing to atmospheric refraction which always elevates the Sun in a vertical direction, dial time is a trifle too fast in the forenoon and too slow in the afternoon, but the effect is too small to be considered in the construction of dials which even when most carefully made, do not admit of any great degree of accuracy.

The earliest record of sun-dials which we possess dates from about 712 B. C. and is found in II Kings, Chap. 20, v. 9-11, which are as follows:

"And Isaiah said, This sign shalt thou have of the Lord, that the Lord will do the thing that he hath spoken: shall the shadow go forward ten degrees or back ten degrees?"

"And Hezekiah answered, It is a light thing for the shadow to go down ten degrees: nay, but let the shadow return backward ten degrees. And Isaiah, the prophet, cried unto the Lord, and he brought the shadow ten degrees backward by which it had gone down in the dial of Ahaz."

And as if this were not enough to impress all future generations, the prophet Isaiah himself referring to the same subject in his Book of prophecy, Chap. 38, v. 8, says, "Behold, I will bring again the shadow of the degrees, which is gone down in the sun-dial of Ahaz, ten degrees backward. So the Sun returned ten degrees, by which degree it was gone down."

And here we may ask, why the sun-dial of Ahaz? Would not any other sun-dial have served the same purpose?

This is regarded by most people as a miracle and a first class one at that, equalling if not surpassing the alleged performance of Joshua; he only made the Sun stand still but Isaiah not only made the Sun come to a standstill but also made it go backwards to such an extent that the shadow on the sun-dial of Ahaz retrograded ten degrees, then brought it to a standstill again and allowed it to resume its ordinary course. This extraordinary movement of the Sun implies, as we now know, corresponding changes in the diurnal motion of the Earth—charges which did not and could not take place without disastrous consequences to our globe. There was no suspension of the laws of motion, nor did the Earth experience the slightest disturbance. Moreover, we have no evidence that the Creator has ever violated or could violate His own laws. These and similar passages are accepted by many people "on faith" which, in many cases, is very elastic. Theologians and pulpit orators push them aside, not being able to offer any rational or intelligent explanation. In the hands of sceptics and infidels, they have contributed not a little to discredit the Scriptures in many quarters.

In this paper we purpose to discuss the subject mathematically and to show by the rigorous formulæ of mathematics, that this apparently extraordinary conduct of the sun-dial of Ahaz, is not only possible from an astronomical point of view but that the statement of the prophet is, without the shadow of a doubt, literally and absolutely true.

The sacred record does not inform us as to the form of the dial or the latitude of the place for which it was constructed. It will therefore, be necessary for a better understanding of the subject to refer briefly to the history of dials and to their form and construction in general.

The Chaldean astronomer, Berosus, who lived about 540 B. C., was the first to construct hemispherical dials. These consisted of a hollow hemisphere, with its rim placed truly horizontal, and a small bead or globule supported in any way at its centre. When the Sun was above the horizon, the shadow would fall on the in-

side of the hemisphere and during the course of the day, would describe an approximately circular arc which could be divided into any number of equal parts, which indicated what were then called *temporary hours*. At the equinoxes the shadow would describe a great circle and at all other times, arcs of small circles, and of these a large number would evidently be required, owing to the variable declination of the Sun. This form of dial was very difficult to construct and could only furnish a rough approximation at the best. It is in every respect inferior to the ordinary and more simple horizontal or declining dial, with which the ancients were also familiar, and of which we shall speak presently.

About the middle of the last century (1746-1762), four hemispherical dials were discovered in Italy, one of which probably belonged to Cicero as he states in one of his letters that he sent a sun-dial to his villa at Tusculum, now Tivoli, where it was found. Another was unearthed at Pompeii, and an eminent German authority (Martini), who carefully examined it, says that it was constructed for the latitude of Memphis in Egypt. This fact is important as showing that in ancient times dials were erected in latitudes differing by many degrees from those for which they were constructed, an adjustment to the original latitude being in such cases always necessary. About the year 290 B. C., Papirius Cursor erected the first sun-dial at Rome. This dial had been taken from the Samnites, who probably obtained it from Greece or Egypt. In the year 261 B. C., Valerius Messala brought a dial from Catania in Sicily and erected it in the forum. Here is another instance of a dial being erected in a locality about five degrees north of the place for which it was constructed. This also was, no doubt, the work of a foreign artist, for a dial was not actually constructed at Rome until the year 164 B. C.

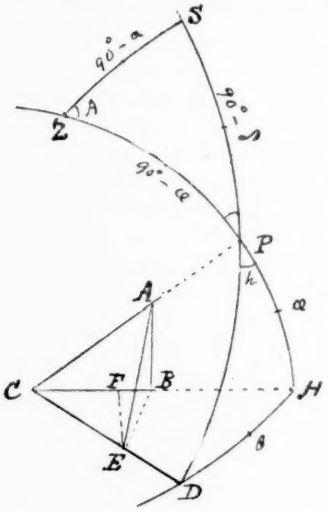
Herodotus informs us that the ancient Greeks obtained their knowledge of sun-dials from the Babylonians, and the extensive acquaintance of geometry which the former possessed, enabled them to construct dials of great excellence, some of which are still in existence. One of the most interesting monuments of antiquity is the Tower of the Winds at Athens; its form is that of a regular octagon, on the faces or sides of which eight different dials are shown—four facing the cardinal points and the other four the intermediate points. Meton erected the first sun-dial in Athens in B. C. 433, and portable dials are said to have been in use in China in very ancient times.

Ptolemy, in his Syntaxis, describes the construction of ordinary horizontal and vertical dials by means of his analemma, an instrument which he invented and which enabled him to solve graphically many astronomical problems.

The Arabians, in both ancient and mediæval times, were very expert in the construction of dials, surpassing even the Greeks themselves.

The horizontal dial is the simplest, the most easily constructed and adjusted, and doubtless the most ancient, consisting at first of a vertical style or pillar erected on a horizontal plane, at the centre of a series of concentric circles as already stated, and subsequently of an inclined style placed in the plane of the meridian and having an elevation equal to the latitude of the place—a form which admits of no further improvement or simplification. The sun-dial of Ahaz must have been of this kind as no other form could produce such apparently extraordinary results.

When we stand on the south side of an ordinary horizontal dial with our face towards the north, we observe the shadow of the style moving from left to right, that is, in the same direction as the hands of a clock or watch. In fact the early clock makers took the sun-dial for their model and arranged the mechanism so that the hands moved in the same direction.



We will first determine the locus of the extremity of the shadow on the horizontal plane. In the diagram, let ABC be the style and CE the boundary line of the shadow on the plane of the dial, B be the origin, BH the initial line, and x, y the coördinates of E; draw EF perpendicular to BH, and let the angle $EBF = A$, the Sun's azimuth, $AEB = \alpha$ the Sun's altitude and $AB = a$, the perpendicular height of the style.

Then $\cos A = \dfrac{x}{\sqrt{x^2 + y^2}}$, $\sin \alpha = \dfrac{a}{\sqrt{x^2 + y^2 + a^2}}$, $\cos \alpha = \sqrt{\dfrac{x^2 + y^2}{x^2 + y^2 + a^2}}$

and from the triangle ZSP in which $SP = 90 - \delta$, $ZP = 90 - \varphi$ and $ZS = 90 - \alpha$, we have

$$\sin\delta = \sin\alpha \sin\varphi + \cos\alpha\cos\varphi\cos A$$

and substituting the above values of cos A, sin α and cos α we have after some easy reductions

$$(\sin^2\delta - \cos^2\varphi)\, x^2 + \sin^2\delta . y^2 - a\sin 2\varphi . x + a^2(\sin^2\delta - \sin^2\varphi) = 0 \quad (1)$$

which is the equation of a conic section, and therefore when

$$\delta + \varphi \begin{cases} > 90^\circ, \text{ the locus is an ellipse} \\ = 90\ , \quad " \quad " \text{ parabola} \\ < 90\ , \quad " \quad " \text{ hyperbola} \end{cases}$$

We may here note some special cases

1. If $\varphi = 0$ or the place is on the equator, we shall have

$$\cos^2\delta . x^2 - \sin^2\delta . y^2 = a^2\sin^2\delta$$

which is a hyperbola.

2. If $\varphi = 90^\circ$ or the pole, we have

$$x^2 + y^2 = a^2\cot^2\delta$$

which is a circle.

3. If $\delta = 0$ or the Sun is on the equator we easily find

$$x = -a\tan\varphi,$$

which represents a straight line parallel to the axis of y.

4. If $\delta = \varphi = \omega$, the obliquity of the ecliptic, we find

$$\cos 2\omega . x^2 - \sin^2\omega . y^2 + a\sin 2\omega . x = 0$$

which also represents a hyperbola.

If we conceive the three planes *ABC*, *CBE* and *ACE* to be produced indefinitely they will determine on the celestial sphere a right spherical triangle *PHD*, in which *PH* is the latitude of the place and the angle *HPD*, the hour angle. The arcs *HP* and *DP* produced will pass through the zenith and the Sun respectively; join *ZS*, and let $HP = \varphi$, $HPD = h$, *HD* which measures the angle $HCD = \theta$ and *PZS*, the Sun's azimuth $= A$.

Then from the right spherical triangle *PHD* we have

$$\tan\theta = \sin\varphi\tan h \quad (2)$$

This equation enables us to determine the boundary line *CE* of the shadow for every hour, half hour, quarter hour and so on.

If the plane *HCD* is not horizontal but inclined to the horizon by an angle ψ and still perpendicular to the plane of the meridian *HPC*, we shall then have $PH = \varphi - \psi$ and the angle *HPD* remaining as before formula (2) becomes

$$\tan\theta = \sin(\varphi - \psi)\tan h \quad (3)$$

This is in fact the formula for computing a horizontal dial for a

latitude equal to $(\varphi - \psi)$; therefore if a horizontal dial constructed for a given place, be carried to any other place, it will be an inclined dial for the latter place and its inclination to the horizon will be equal to the difference of the latitudes of the two places; thus suppose a horizontal dial constructed for Lat. 18° *N* be carried to a place in Lat. 38° *N*, it must be placed at an inclination of 20° to the horizon in order that the elevation of the style may be equal to 38°, that is to say, the south side of the dial must be tilted downwards through an angle of 20°, the difference of the latitudes, the plane of the style coinciding of course with the plane of the meridian of the place. The ancients were acquainted with this form of dials, for we have already cited two such cases; the first a dial found in Pompeii but constructed for the latitude of Memphis and the second one erected in the Roman Forum but made for the latitude of Catania some 5° south.

From the spherical triangle *PZS* we have

$$\cot A = \frac{\tan \delta \cos \varphi - \sin \varphi \cos h}{\sin h}$$

$$= \tan \delta \cos \varphi \operatorname{cosec} h - \sin \varphi \cot h \qquad (4)$$

Now if during the day, the Sun's azimuth has a maximum value, the second member of the last equation must be a minimum, and to determine whether this is the case or not we differentiate equation (4) and put the differential co-efficient equal to zero, δ and φ being regarded as constant, thus

$$\frac{d.\cot A}{dh} = -\tan \delta \cos \varphi \cot h \operatorname{cosec} h + \sin \varphi \operatorname{cosec}^2 h = 0$$

Cancelling the common factor and solving we obtain

$$\cos h = \frac{\tan \varphi}{\tan \delta} \qquad (5)$$

which is possible only when $\delta > \varphi$ or when the Sun crosses the meridian *north* of the zenith of the dial.

Equation (5) also shows that when the azimuth attains its maximum value, the triangle *P Z S* is right angled at the Sun, or in other words, the Sun is at his greatest elongation east or west as the case may be.

If then the Sun transits north of the zenith, the shadow of the style will move forwards from sunrise to the instant of greatest elongation; it will remain stationary for a moment and then move backwards until the Sun attains his greatest western elongation, when it will again advance.

Now the latitude of Jerusalem where the dial of Ahaz was erected, is about 32° N or about 8½° north of the Tropic of Cancer and therefore the Sun could never transit north of its zenith.

The dial of Ahaz must therefore have been an inclined one constructed for some place whose latitude was less than 23½°, so that when erected at Jerusalem, its zenith was, about the time of the summer solstice, between the equator and the point of the Sun's transit and consequently the Sun's azimuth would have two maximum values between sunrise and sunset, the shadow would therefore go backwards on the dial during the interval in which the Sun was passing from his eastern to his western elongation, and he would also apparently move backwards during the same interval, because from sunrise to the eastern elongation, his motion would be eastward, then westward to the western elongation and then eastward again till sunset.

Of course when the declination of the Sun became less than the latitude of the zenith of the dial, the shadow would move forward during the whole day; the phenomenon could therefore only take place at or near the summer solstice.

The Hebrews never devoted themselves to the study of mathematics and astronomy, nor in fact to any of the other physical sciences. The dial of Ahaz was no doubt the work of a foreign artist in Egypt or Southern India, most probably the latter. If constructed in Egypt it must have been south of Syen or in upper Egypt on the border of Nubia, but we have no evidence that the people of that region were at that date far enough advanced in the arts and sciences to be able to construct such instruments. The ancient Hindoos however have left behind them abundant evidence of their ability as mathematicians and astronomers and were doubtless fully competent to construct any form of dial.

Although Descriptive Geometry is regarded as a comparatively recent invention—the work of the eminent French Geometer Monge—yet it is very probable that the Hindoo Geometers were able to solve the triangle *PHD* graphically and to lay down the lines of the shadow for the several hours, with all the accuracy necessary, and when a dial was once accurately constructed it could be copied indefinitely and the duplicates exported to foreign countries with instructions for their adjustment in other latitudes. In this way the dials of India, Babylon and Egypt found their way to Palestine, Greece and Italy for at the date referred to and for many centuries before, an extensive commercial intercourse existed between the former countries and those bordering on the Mediterranean.

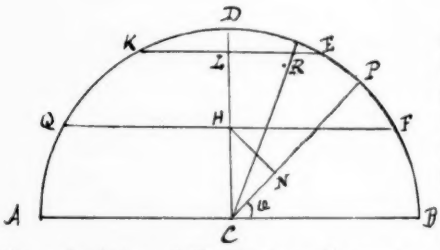
Let ADB be a semi-circle, divide the quadrant DB into six equal parts of 15° each—we have only divided it into three equal parts of 30° each to avoid an excessive number of lines—take PCB equal to the latitude φ; draw the chords KE, QF, etc. cutting DC in L, H, etc.; draw HN perpendicular to PC and make LR equal to CN, join CR and produce it to meet the semi-circle, then CR will be the two o'clock hour-line of the shadow.

For HC being the sine of 30° or sin h we have

$$\begin{aligned} \sin h \sin \varphi &= CN \\ &= LR \\ &= LC \tan LCR \\ &= \cos h \tan \theta \end{aligned}$$

whence $$\tan \theta = \sin \varphi \tan h$$

which is Eq. 1.



This construction is quite simple and completely avoids the more complicated processes of Descriptive Geometry. In fact, the hour angles may be laid down by means of the accompanying construction, involving only the principles of Elementary Geometry.

To determine the angle through which the shadow went backwards in terms of the latitude and declination we must eliminate h from (2) and (5); thus from (2) we have

$$\begin{aligned} \tan \theta &= \sin \varphi \tan h \\ &= \frac{\sin \varphi \sin h}{\cos h} \\ &= \frac{\sin \varphi \sin h}{\tan \varphi \cot \delta} \qquad (6) \\ &= \frac{\cos \varphi \sin h}{\cot \delta} \end{aligned}$$

whence $$\sin h = \frac{\tan \theta \cot \delta}{\cos \varphi} \qquad (7)$$

Squaring (5) and (7) and adding, we find

$$\frac{\tan^2 \theta + \sin^2 \varphi}{\cos^2 \varphi \tan^2 \delta} = 1$$

whence

$$\tan^2 \theta = \cos^2 \varphi \tan^2 \delta - \sin^2 \varphi$$

$$= \frac{\cos^2\varphi - \cos^2\delta}{\cos^2\delta}$$

$$= \frac{(\cos\varphi + \cos\delta)(\cos\varphi - \cos\delta)}{\cos^2\delta}$$

$$= \frac{\sin(\delta + \varphi)\sin(\delta - \varphi)}{\cos^2\delta}$$

and $$\tan\theta = \pm\frac{\sqrt{\sin(\delta + \varphi)\sin(\delta - \varphi)}}{\cos\delta} \qquad (8)$$

which is possible only when $\delta > \varphi$, or when the Sun crosses the meridian north of the zenith of the dial, φ being in all cases the latitude of the place for which the dial was constructed.

It will also be observed that θ has two values by reason of the double sign, that is the shadow will go back through double of the angle whose tangent is $\frac{\sqrt{\sin(\delta + \varphi)\sin(\delta - \varphi)}}{\cos\delta}$, and from (2) we have

$$\tan h = \frac{\tan\theta}{\sin\varphi}$$

$$= \frac{\sqrt{\sin(\delta + \varphi)\sin(\delta - \varphi)}}{\cos\delta\sin\varphi} \qquad (9)$$

which gives half the interval during which the shadow moved backwards, or the interval from either elongation to noon.

The conduct of the dial of Ahaz was therefore not miraculous but the result of natural causes.

The prophet as well as Hezekiah himself, was no doubt ignorant of this property of sun-dials and his question was doubtless prompted by a divine influx or impulse for which he was not responsible. The astronomical phenomenon however served the purpose of a sign to Hezekiah that the promise made would be fulfilled.

If they had observed the dial for several successive days they would have probably found the same thing which would have further confirmed the sign; and if observed some weeks or months afterwards they would have found the shadow constantly moving forward—a circumstance which would have created no doubt in their minds since a further confirmation of the sign was now no longer necessary.

The reader who may not be able to follow the mathematical proof just given, can obtain a clear view of the phenomenon by considering the case of the diurnal motion of a circumpolar

star—one in Ursa Major or the Great Dipper, for instance. Suppose the star is at its lower transit or below the pole, it is then due north of the observer. As it ascends the celestial vault it moves eastward until it attains a point where it appears for a moment to move straight up—the point of greatest eastern elongation—it then changes its apparent course and moves westward, crossing the meridian north of the zenith and continuing its westward motion until it arrives at its greatest western elongation, when it now for a moment appears to move straight down and then again moves eastward until it arrives at its greatest eastern elongation. Now if it were brilliant enough to cast a shadow we would evidently find that the shadow of a vertical pillar or style would first move forward on a horizontal plane until the star arrived at its greatest elongation, when it would remain stationary for a moment and then move back until the greatest western elongation, when it would again change its direction and move forwards. This is just what occurred with the sun-dial of Ahaz—the Sun taking the place of the star, that is to say, the Sun crossed the meridian north of the zenith of the dial. There was, therefore, no miracle but simply an ordinary astronomical phenomenon, which at certain times and under certain circumstances can happen anywhere. This is not the only astronomical phenomenon alluded to in the Bible, capable of a scientific explanation but we cannot discuss them just now. There are, however, many things recorded therein which cannot be so explained. They admit, however, of a rational and intelligent treatment when considered from the proper standpoint, and although an Astronomical Journal is not the most appropriate place for the discussion of miracles in general, the following brief allusion to them may not be out of place.

The human body was made for a temporary dwelling place of the soul or spirit, and not the reverse. The former is "of the Earth, earthy," returns to the earth and will never again be resumed, but the latter will enjoy a perpetual existence in the spiritual world; it must be of the same form, possess all the senses in an eminently exalted degree and perform all the functions which it did when temporarily residing in the body; it must be so, otherwise we would lose our identity and be no longer the same individuals we are here. While in the body it exercised the functions of the senses—sight, hearing, etc.—through material organs by which its powers were immeasurably diminished. Here we see as if "through a glass darkly," but there are numerous instances recorded in the Scripture where this material organ has been

pushed or set aside, as it were, and the spiritual function allowed to display its full activity.

The burning bush seen by Moses, the scene witnessed by Elijah and his servant, Joshua's stationary Sun, Saul's experience with the witch of Endor, the Transfiguration, the Star of Bethlehem and the scenes described in Chap. 27 v. 53 of Matthew and Chap. 21 of John, the circumstances attending the conversion of St. Paul and all the scenes alluded to in the Book of Revelation, were all seen or heard by the spiritual faculties and not through the agency of the material organs. They were witnessed or heard in the spiritual world and not in the material. The change was in the individuals and not in the things seen or heard. The experience of Elijah's servant proves this, and if the record is true and we believe it is, one such statement is just as conclusive as a hundred thousand. Moreover, the Apostle John states again and again in the Apocalypse that when he saw and heard the things there described, he was "in the spirit," that is, seeing and hearing as to his spiritual senses, and he frequently asserts that they are true for he says, "I, John, saw and heard them." There are also numerous well authenticated instances of persons obtaining glimpses or visions of the spiritual world just prior to their departure from this. These manifestations are usually regarded by most persons, as hallucinations or the results of disordered mental faculties, but we really know nothing about them. This reminds us of the practice of chemists half a century or more ago; when they found a phenomenon which they could not explain—and this happened very frequently—they referred it to catalytic action, the result of catalysis, whatever that may be.

The so-called miracles are all capable of a rational explanation—an explanation too which does no violence to the laws regulating matter, but which is in strict accord either with well known scientific principles or with what has been revealed to us of the spiritual nature of man.

1757 P St. N. W., Washington, D. C.

Nov. 5, 1898.

THE PROPER MOTION OF CERTAIN STARS AS A CRITERION OF THEIR DISTANCE.

J. G. PORTER.

For Popular Astronomy.

There is perhaps no problem in practical astronomy much more difficult than the determination of the distance of the stars:

hence any consideration which will tend even indirectly to enlarge our knowledge of this subject is to be welcomed. For the suggestion that I here make I claim no originality; it is in fact so simple that it must occur to any one dealing with the subject; but I am not aware that it has ever been put to any practical test.

In the ordinary determination of stellar parallax we employ the Earth's orbital motion to shift us from one point of view to another. Since the direction and rate of the solar journey through space are now approximately known, why can we not utilize this motion to furnish us our base-line? In other words is it not possible to tell something from the direction and amount of a star's proper motion as to how far away it is likely to be?

It has already been shown in several recent investigations that the proper motion of the stars is a much better criterion of their distance than brightness. In fact we may assume with considerable certainty that the average distance of large groups of stars is inversely proportional to the amount of their motion. My present suggestion is as to whether it may not be possible to extend this principle to smaller groups, and even with some probability to individual stars.

We find in those regions of the heavens which are approximately 90° from the apex of the Sun's way, a good many stars whose motion appears to be parallactic, that is, they are drifting almost directly away from the point in the sky towards which the solar system is moving. This must impress anyone who looks through an extensive catalogue where the proper motions are given. Two objections may be urged against making use of this drift to determine the distance of these stars. In the first place it may be said that it is reasoning in a circle to discover the solar motion through the movements of the stars, and then use this motion to measure their distances. But while this is true to a certain extent, I do not apprehend that it will seriously vitiate our reasoning, since the solar motion is equally shown by other classes of stars. A more serious objection is that it is impossible in the case of any given star to know surely that its motion is purely parallactic, and not partly at least due to the *motus peculiaris* of the star itself. Manifestly the only way to arrive at certainty on this point is to measure the star's parallax in the ordinary manner; but at the same time it is to be remarked, that since no general law governing the movements of the stars has yet been discovered, the probability that many stars in the same region of the sky would be moving directly away from the apex

of the Sun's motion is extremely small; and therefore, on the other hand, *the probability that this apparent movement is really parallactic is very great*. Moreover, the star's actual motion is just as likely to be towards the apex as away from it, and in such cases the star must be nearer to us than its apparent movement would indicate.

My conclusion is, then, that while any computations of actual distance based on the proper motion of these stars must be subject to considerable doubt, yet their remoteness as a class may be pretty accurately gauged; and further, that here lies a most promising field for the parallax searcher, since a careful measurement of the annual parallax of these stars will almost certainly give a large percentage of results.

As an illustration of the method here suggested, Mr. E. I. Yowell has formed two groups of stars in those regions of the sky where the parallactic proper motion in right ascension would be nearly zero. Assuming the apex of the solar motion to be in 18^h, $+ 40°$, the maximum motion in declination would be at 6^h, $+ 50°$, and 18^h, $- 50°$. As it was impossible to get many stars in the southern group near declination $- 50°$, owing to our lack of data for the southern portion of the sky, stars as far north as the equator had to be included.

Only the last column, headed "Assumed parallactic motion," needs explanation. If we assume that the whole movement of these stars is parallactic, it is evident that this motion will be foreshortened in proportion as the star's position approaches to the apex or anti-apex of the Sun's way. This column, then, gives the motion as it would be if the Sun were moving at right angles to the line of sight.

For Group I the average parallactic motion is a quarter of a second. Adopting twelve miles per second as the rate of the Sun's motion, we are traveling yearly four times the length of the radius of the Earth's orbit, and therefore the annual parallax would be one-fourth of the parallactic motion. The average distance of this group would then be 52 light-years. Only two of these stars have, so far as I know, been actually measured, α Aurigae and β Tauri; and in each case the resulting parallax, respectively $0''.10$ and $0''.06$, very nearly fulfills the above condition.

GROUP I.

Name.	Mag.	R. A.	Decl.	Proper Motion.		Assumed Parallactic Motion.
				$\Delta\alpha \cos\delta$	$\Delta\delta$	
		h m	°	″	″	″
Lal. 8840	8.5	4 37	+ 27.5	+ 0.02	− 0.34	0.36
4 Camel	6	39	+ 56.6	+ 0.03	− 0.16	0.16
Brad. 671	6.5	53	+ 66.7	+ 0.06	− 0.35	0.37
9 Aurigæ	5	58	+ 51.5	− 0.03	− 0.17	0.17
O. Arg. 5500	9	59	+ 55.3	0.00	− 0.41	0.41
α Aurigæ	1	5 09	+ 45.9	+ 0.08	− 0.42	0.43
16 Aurigæ	5.5	11	+ 33.3	+ 0.03	− 0.16	0.17
β Tauri	2	20	+ 28.5	+ 0.02	− 0.18	0.20
Lal. 10164	7	21	+ 33.7	0.00	− 0.17	0.18
Weisse 5h, 662	8.5	25	+ 15.7	− 0.03	− 0.37	0.45
Rümk. 1464	8.5	27	+ 20.0	0.00	− 0.33	0.38
Lal. 10397	8.5	27	+ 15.9	+ 0.03	− 0.15	0.18
Lal. 10484	8.5	32	+ 55.0	0.00	− 0.13	0.13
P. 5h. 146	6.5	33	+ 53.4	− 0.02	− 0.54	0.54
P. 5h, 218	8.5	42	+ 15.7	− 0.03	− 0.15	0.18
Lal. 10978	9	43	+ 32.1	0.00	− 0.11	0.12
Lal. 11145	8	48	+ 12.4	0.00	− 0.29	0.37
39 Aurigæ	6.5	58	+ 43.0	− 0.03	− 0.15	0.16
22 H. Camel	4.5	6 08	+ 69.4	− 0.01	− 0.11	0.12
43 Aurigæ	6.5	10	+ 46.4	0.00	− 0.15	0.15
6 Lyncis	6	22	+ 58.2	− 0.03	− 0.33	0.34
Fed. 923	7.5	24	+ 54.9	− 0.02	− 0.17	0.17
Weisse 6h, 883	7	32	+ 12.3	− 0.07	− 0.28	0.35
Groom. 1214	7	37	+ 40.7	− 0.03	− 0.19	0.19
Lal. 12867	7	38	+ 39.5	0.00	− 0.15	0.15
60 Aurigæ	6.5	46	+ 38.5	+ 0.02	− 0.19	0.19
15 Lyncis	4.5	48	+ 58.6	0.00	− 0.12	0.12
Lal. 13425	8.5	52	+ 28.8	− 0.02	− 0.12	0.13
P. 6h, 329	8	7 02	+ 15.7	− 0.04	− 0.22	0.27
O. Arg. 7618	8.5	05	+ 52.8	0.00	− 0.21	0.21
Groom. 1281	6	08	+ 47.4	+ 0.01	− 0.18	0.18
Weisse 7h, 635	8.5	24	+ 19.2	+ 0.03	− 0.41	0.48
Average	6.8					0.25

The average parallactic motion for Group II is 0″.26, and the corresponding distance 50 light years. This is in most satisfactory agreement with the first group, especially in consideration of the fact that the proper motions are not as reliable and the distribution of the stars not as favorable. That the average distance of these 59 stars is very close to fifty light years, I have very little doubt. When it comes to the individual stars, much greater uncertainty of course prevails. It is not to be expected that the parallax of each star will prove to be approximately one-fourth of its parallactic motion; yet as the chances are even that the star is nearer rather than more remote than the motion would indicate, it would seem worth while to test the question by actual measurement. Should this be done with favorable re-

sults, the principle might then be extended to other portions of the sky.

GROUP II.

Name.	Mag.	R. A.	Decl.	Proper Motion.		Assumed Parallactic Motion.
				$\Delta\alpha \cos\delta$	$\Delta\delta$	
		h m	°	″	″	
Lal. 30479	7.5	16 41	− 19.9	+ 0.01	− 0.12	0.14
ε^2 Arae	5.5	55	− 53.1	− 0.04	− 0.16	0.16
P. 16h, 260	6.5	55	− 13.4	− 0.04	− 0.33	0.42
Lacl. 7111	6.5	58	− 28.4	+ 0.09	− 0.28	0.31
η Scorpii	4	17 04	− 43.1	0.00	− 0.30	0.30
P. 16h, 309	7	05	− 20.5	− 0.03	− 0.14	0.16
Lal. 31478	7.5	14	− 7.9	− 0.01	− 0.20	0.28
Lal. 31485	6	14	− 5.8	0.00	− 0.17	0.23
W. Arg. 13303	7.5	16	− 19.5	+ 0.02	− 0.23	0.27
44 Ophiuchi	4.5	20	− 24.1	− 0.03	− 0.12	0.14
45 Ophiuchi	5	21	− 29.8	− 0.02	− 0.14	0.15
W. Arg. 13440	8.5	27	− 21.7	+ 0.03	− 0.25	0.28
Lal. 32422	7.5	41	− 7.9	0.00	− 0.13	0.17
Lacl. 7432	6	46	− 65.7	0.00	− 0.42	0.43
Lal. 32664	7.5	47	− 7.9	− 0.04	− 0.23	0.31
Lal. 32723	7.5	49	− 3.4	0.00	− 0.16	0.22
π Pavonis	6	59	− 63.7	0.00	− 0.23	0.23
P. 17h, 365	8	18 03	− 26.1	− 0.09	− 0.30	0.32
Brad. 2293	6.5	11	− 3.0	0.00	− 0.27	0.40
λ Sagittarii	4	21	− 25.5	− 0.07	− 0.19	0.21
Brad. 2330	4.5	29	− 8.3	− 0.04	− 0.31	0.42
Lal. 34442	7.5	31	− 4.7	+ 0.04	− 0.18	0.26
Lacl. 7785	5	36	− 65.0	0.00	− 0.17	0.17
γ Coronae Aust.	5	59	− 37.2	+ 0.08	− 0.31	0.32
Lacl. 8011	7	19 06	− 58.2	0.00	− 0.21	0.21
Lacl 8117	7	23	− 31.0	− 0.01	− 0.25	0.26
P. 19h, 166	7	29	− 21.0	+ 0.04	− 0.18	0.21
Average	6.2					0.26

CINCINNATI OBSERVATORY,
Nov. 15, 1898.

THE LEONID METEORS OF 1898.

C. D. PERRINE.

FOR POPULAR ASTRONOMY.

As the time approaches for another great shower of the *Leonid* meteors, interest is renewed in this branch of astronomy. A keen interest is felt by the astronomers as well as the lay public, for besides the spectacle of a considerable shower, which is fascinating to every one, there are mysterious connections of this swarm with a comet discovered by Tempel, having a period of

about 33 years. It is in hopes of solving completely this connection that the astronomer gives so much attention to them. It will not be out of place to again call attention to this as an especially fruitful field for amateurs who are desirous of doing observational work. It is a piece of work requiring no instrumental equipment whatever; and the most valuable results, viz.: the determination of the frequency of the meteors, requires no preliminary training; the location of the radiant in the sky and the patience to count the meteors coming from this point are the only requisites. Too many observations of this kind cannot be made and it is to be hoped that a great many will undertake this work for the showers of the next few years.

The weather conditions at Mt. Hamilton have been very good during the past week, and this, coupled with the fact that there has been no Moon to interfere, has made it a very favorable apparition.

The following table will show at a glance the general results of the observations.

Date.	Time.		Interval.	No. of Meteors.	Aver. per hour.
1898.	h m	h m	h m		
Nov. 11	13 20	to 15 10	1 50	8	4.4
12	12 55	14 55	2 0	10	5.0
13	13 0	16 30	3 30	38	10.9
14	13 38	13 53	0 15	8	43.8
14	14 24	16 0	1 36	73	
15	13 15	13 45	0 30	4	8.0
16	13 37	14 7	0 30	8	14.0
16	15 2	15 32	0 30	6	

From the above results it will be seen that there was but a very moderate number before and after the 14th, the maximum occurring umistakably on this date. It should be borne in mind that some meteors would not be seen by a single observer, and hence the actual number will be higher than that given, but as all the observations were made under as nearly the same conditions as possible, the results are entirely comparable.

On the nights of the 11th, 12th and 13th the paths of all meteors seen within the limits of the map were charted, as the Leonids were not sufficiently numerous to require one's entire attention. On the 14th the map used was not so extensive and but few meteors were seen within its limits. On the 15th and and 16th no attempt was made to chart the few observed. On the first three nights the Leonids were in the minority. A large percentage on these nights were observed to come from the direc-

tion of *Gemini*. The characteristics of the Leonids, viz:—strong trains, rather slow motion and their bluish or greenish white color were very plain. These features served to identify them fully so that it was feasible to reject some which seemed to come from this radiant; this was done in the case of two on the 13th. The paths of the meteors were charted with reference to neighboring stars and general directions in the sky, independently of the radiant point. Later the paths were extended and many were found to vary widely from the usually accepted radiant, in fact the meteors seemed to have come from almost all parts of the "Sickle." There is considerable error to be expected in this method of charting, and also some error due to distortions of the map, but not enough to account for all of the observed variation. On the 14th and subsequent nights when no charting was done especial attention was paid to this point, and the fact was confirmed that the paths of a number of meteors, when extended backward, did not touch the usual radiant point, but passed some distance from it.

Not only were the meteors most *numerous* on the night of the 14th but the brightest ones were seen then. Two were especially fine. The first and brightest became visible at $13^h\ 46^m\ 44^s$ P. S. T. and lasted two or three seconds. It came almost exactly from the radiant and passed north of δ Leonis where it exploded. Its visible path was not over ten degrees, its motion being rather slow. Towards the end of its flight it brightened up rapidly; it was 30 to 40 times as bright as Venus at its maximum. As it brightened its color became a light but brilliant green.

After the disappearance of the meteor the debris cloud was a very conspicuous object, much larger than the Andromeda Nebula and fully ten times as bright. There was almost no wind at the time, the cloud drifting but slowly and retaining its form and brightness for some time. To the naked eye the meteoric cloud had the appearance of a splendid comet with a tail some 3° long, pointing to the northeast. To the unaided eye its color was a dull, white. About five minutes after it became visible the meteoric cloud was examined with the 4-inch Clark Comet Seeker. Its form as seen in the telescope was quite different from the naked eye view. Its outline was very sharply defined and the surface very irregular and knotty. Beside the main stream of cloud there was a bright branch making an angle of about 60° with the main streamer. In the telescope the color was a decided rose pink. An attempt was made to observe the spectrum with a direct-vision spectroscope but the cloud had become too faint.

Immediately after the fall of the meteor the head of the cloud was in α 11^h 10^m, δ + 24°. At 14^h 13^m the same part of the cloud occupied the position α 11^h 0^m, δ + 16°. The cloud was still plainly visible at 14^h 29^m, 42 minutes after its first apparition. Light streaks of haze and cloud gathered about soon after so that it is not possible to say how much longer than this that it was visible.

At 14^h 37^m 18^s ± 5^s P. S. T. another bright Leonid fell near the eastern horizon. There was considerable haze in this region of the sky, but even through this the meteor was very brilliant, green in color and left a bright cloud where it fell. This cloud was observed with the 4-inch Comet Seeker which showed it to be made up of a bright, central, nearly round mass with two irregular streamers, one on either side. This meteoric cloud was very bright five minutes after the fall, but owing to the thick haze no attempt was made to ascertain the extreme duration of its visibility.

The magnitudes of those observed on the 13th were noted and a comparison of the distributions may be of interest. Of the first magnitude including one rated as bright as Sirius, there were 5; of the second, 8; of the third, 8; of the fourth, 7; and of the fifth and fainter, 10.

It was thought probable that there would be a fine display this year on account of the proximity to the great swarm due in 1899 or 1900 but this expectation has hardly been realized. The Leonids showed a decided increase in numbers on the night of the 14th over previous years and over other nights of this apparition—but yet was far from a "great shower." Should the shower of 1899 be as abundant as is expected, it will be clear that the swarm of meteoric particles is closely formed, at least on the advancing part.

LICK OBSERVATORY, University of California.
1898 November 18.

ORBIT OF COMET *i* 1898 (BROOKS)

W. J. HUSSEY.

FOR POPULAR ASTRONOMY.

From my observations of October 21, 23 and 25, I have computed the elements of the orbit of this comet given below. In the interval embraced by these observations, the comet described a heliocentric arc of a great circle of about 5¼°. During the same

time its movement in geocentric longitude amounted to more than 39°, being confined between the circles of latitude 68° 18′ and 66° 6′. Although the interval between the extreme observations is only four days, the movement of the comet has been so rapid as to afford a reasonably secure basis for the determination of the elements of the orbit.

The elements which I have obtained are as follows:

$$\begin{aligned} T &= 1898\ \text{Nov. } 23.13518\ \text{Gr. M. T.} \\ \omega &= 123^\circ\ 22'\ 21''.3 \\ \Omega &= 96\ 10\ 6\ .2 \quad \text{Ecliptic and Mean Equinox of 1898.0} \\ i &= 140\ 18\ 58\ .1 \\ \log q &= 9.878746 \end{aligned}$$

$$O-C: \quad \Delta\lambda' \cos\beta' = +0''.6, \qquad \Delta\beta = -1''.6.$$

The comparison of these elements with those of the orbits that have been computed at once shows that they are nearly identical with those of the comet 1881 IV, discovered by Professor Schaeberle at Ann Arbor, July 13, 1881. Dr. Stechert, as the result of a definitive investigation of the orbit of this comet, arrived at the following parabolic elements as being those which satisfactorily represent all the observations.

$$\begin{aligned} T &= 1881\ \text{Aug. } 22.3431935\ \text{Berlin M. T.} \\ \omega &= 122^\circ\ 7'\ 18''.61 \\ \Omega &= 97\ 2\ 36\ .93 \quad \text{Mean Equinox 1881.0} \\ i &= 140\ 13\ 54\ .04 \\ \log q &= 9.8017757 \end{aligned}$$

It is to be noted that the longitudes of the nodes and the inclinations of these two orbits are nearly the same, consequently, the planes of the two orbits are nearly coincident. Moreover, the dimensions of the orbits and their positions in their planes, as determined by q and ω, are almost the same. Hence, the two comets describe essentially the same path in space, and the question of their identity arises.

The Comet 1881 IV was under observation from July 13th to October 18th, 1881. During this time it described a heliocentric arc of 167°; namely, 77° before and 90° after perihelion passage. The length of this arc is sufficient to afford a very accurate determination of the orbit, and to give us confidence in the results obtained by Dr. Stechert. The most probable elements which he obtained were hyperbolic, differing so little, however, from the parabolic ones given above that he finally selected the latter as the definitive elements. In his attempts to vary the eccentricity, he found the observations could be represented fairly well by all orbits from an ellipse corresponding to a periodic time of 100,000 years to an hyperbola having an eccentricity equal to 1.0003. If the orbit is included within these limits, as seems reasonably cer-

tain, it is evident that the comet 1881 IV is not one of short period and that it is not identical with the Comet *i* 1898 (Brooks). The two comets, however, may certainly be said to be of the same family.

LICK OBSERVATORY,
Mt. Hamilton, California.
October 26, 1898.

THE NEW PLANET.

GUSTAVE RAVENE.

FOR POPULAR ASTRONOMY.

Mr. Witt, of the Urania Observatory in Berlin, discovered on the 14th of August a small planet, which, according to the subsequent calculations of Mr. Berberich (Berlin) and Prof. Hussey (Mt. Hamilton) moves in an orbit altogether different from the orbits of the other minor planets. In the first place, its mean distance from the Sun places it between the orbits of the Earth and of Mars; secondly, its orbit intersects the path of the latter planet, and then the eccentricity of the orbit is so great that it may approach the Earth to within a distance of about 14,000,000 miles. It is, therefore, next to the Moon, the Earth's nearest celestial neighbor.

Interesting as this discovery is from a purely astronomical standpoint, it is still more important to the Science of Celestial Mechanics, for there arise now several new problems, altogether at variance with the conditions of the Solar System as heretofore known. This planet may produce considerable perturbations in the motions of the Earth and of Mars, and as it intersects the orbit of the latter it will be a question whether the accepted theory of the stability of the Solar System will not have to be subjected to considerable modifications.

The results of my calulations, which I shall now proceed to give, deal with the more general aspects of the problem. I have assumed the disturbing body or bodies to be at a distance from the Sun varying from 1.44 to 1.5 (approximately), the Earth's distance being unity. The eccentricity of the orbit I have taken between the limits 0.1 and 0.3, and as regards the position of the orbit in space I have for the first approximation, as is permissible, supposed it to be in the plane of the ecliptic and the longitude of the perihelion to assume all values from 0 to 2π. On the

basis of these general assumptions, I have deduced the secular variations of the Earth's orbital eccentricity and of its longitude of perihelion. The reader specially interested in this problem will find applicable to its general solution the formulæ given by Laplace in the "*Mécanique Céleste*" (Tom I. Liv. II § 55) or by Ponteconlant, "*Theorie analytique etc.*" Tom I., and by Tisserand "*Méc. Cél.* Tom I." The same problem, with several modifications, and applied to the perturbations of Mars will be found in my paper, "*Sulle perturbazioni prodotti dai piccoli pianeti.*" Academy of Sciences of Turin, 1896-7.

The following table contains the perturbations of the Earth's orbital eccentricity due to the action of these disturbing bodies for two distances $a'=1.4396$ and $a'=1.4527$, for the mean eccentricity $e=0.2$ and for a mass of the disturbing body or bodies equal to one hundred millionth (1/100,000,000) of the Sun's mass.

$\omega' - \omega$	$\delta \frac{de}{dt}$	
	for $a' = 1.4396$	for $a' = 1.4527$
°	"	"
0	0.00	0.00
30	+ 0.00092	+ 0.00082
60	+ 0.00159	+ 0.00149
90	+ 0.00179	+ 0.00172
120	+ 0.00159	+ 0.00149
150	+ 0.00092	+ 0.00082
180	0.00	0.00
210	− 0.00092	− 0.00082
240	− 0.00159	− 0.00149
270	− 0.00179	− 0.00172
300	− 0.00159	− 0.00149
330	− 0.00092	− 0.00082

The expression $\omega' - \omega$ is the difference between the longitude of perihelion of the disturbing body ($\tilde{\omega}'$) and of the longitude of perihelion of the Earth ($\omega = 100° 21' 41''$ for 1850.0). If we introduce the longitude of perihelion of the recently discovered planet we shall have $\omega' - \omega = 19° 14'$ and consequently the perturbations of the eccentricity would be quite small, but it would be otherwise with the secular variation of the perihelion of the Earth which would become $\delta \frac{de}{dt} = - 8''.688$ in a century. Observation does not, so far, guarantee a similar perturbation and hence we are driven to two conclusions, either that the new planet is of very much smaller mass, or that there are many other bodies moving in orbits having the same

distance from the Sun but of different positions in space. It is not impossible that such is the case, on the contrary it is very probable that there are thousands or even millions of very small bodies moving around the Sun and distributed in orbits the dimensions and positions of which are regulated by the gravitational action of the other planets.

But every perturbation in the Earth's orbital eccentricity will make itself felt in the secular acceleration of the Moon's mean motion. The annual variation of the Earth's orbital eccentricity is quite imperceptible but the effect in the longitude of the Moon becomes very pronounced when we compare theory with observations extending over hundreds or even thousands of years. The researches of Laplace, Ponticonlant, Plana, Hansen, Adams, Delauncy, Cayley, and others have treated this problem very completely and it is only my intention here to point out that the introduction of a small term depending on the action of a small planet between the Earth and Mars would produce a slight, but by no means immaterial, variation of the secular acceleration of the Moon's mean motion.

The general expression for these secular terms in the Moon's longitude is

$$-\left(\frac{3}{2}m^2-\frac{3771}{64}m^4-\frac{34047}{64}m^5\right)n\int(e'^2_0-e'^2)\,dt$$

and Delannay has found the complete value to be 6″.11. If we limit ourselves at present to the first term and introduce into it Leverrier's value for the secular variation of the Earth's orbital eccentricity namely $\frac{de}{dt}=-0''.08755$, we would find it to be

$$10''.35\left(\frac{t}{100}\right)^2$$

but if we introduce the values for $\delta\frac{de}{dt}$ found for case I, namely $+0''.00159$ and $+0''.00179$, we will find

for $\omega'-\omega=60°$; $= 10''.16\left(\frac{t}{100}\right)^2$

$\omega'-\omega=90$; $= 10''.14\left(\frac{t}{2}\right)^2$

and the other terms would also be sensibly altered.

Summing up the above calculations we may state that a body or system of small bodies between the orbits of the Earth and Mars would produce a slight secular variation in the Earth's

orbital eccentricity which in its turn would manifest itself quite appreciably in the theoretical value of the secular acceleration of the Moon's mean motion. The total mass of these bodies is not above 1/100,000,000 of the Sun's mass and very likely is very much less, as this mass distributed over an orbit having the dimensions and position in space like that of the new planet *D Q* would produce a noticeable secular variation in the longitude of the Earth's perihelion, not yet disclosed by observation. No doubt, however, can exist that it is necessary to take into account the action of these small bodies in every mathematical theory dealing with motion of the interior planets, the secular variation of the elements and the general theory of the stability of the Solar System.

CLARK UNIVERSITY, Worcester, Mass.

COMET 1846 VI.

H. P. TUTTLE.

FOR POPULAR ASTRONOMY.

Professor Payne in his most admirable articles on Comet Families, recently printed in POPULAR ASTRONOMY, has shown that while the giant planet Jupiter has immediate control of half-dozen or more small comets, Saturn, so far as yet known, has but two. These are: Comet VI, 1846 (Peters) and Comet I, 1858 (Méchain-Tuttle). Of the former of these comets the writer has something to say which has never before been published.

As many of our readers well know, this comet was discovered in Sicily, in 1846, by the late distinguished Professor C. H. F. Peters, Director of the Litchfield Observatory of Hamilton College, N. Y. The observations extended over a period of about one month and were made with a small telescope armed with a ring micrometer.

In December, 1858, Drs. Peters and Brünnow paid a few days' visit to Harvard College Observatory, and while there Dr. Peters informed the writer that he had nearly completed a sweeping ephemeris for comet VI, 1846, and as soon as finished he would send me the work complete as would not be able search for the comet, having no comet-seeker, and the great uncertainty of the comet's place would not warrant him in wasting time with his 13-inch equatorial, and, moreover, he had other work already laid out for the ensuing year.

Late in February, 1859, the writer received the sweeping

ephemeris from the Doctor. The ephemeris began about the first of April and extended over a space of about three months. I began the search a little ahead of time with the improved 4-inch Bowditch comet-seeker (Broken-back) and such a "scouring" of the heavens covered by the ephemeris as was performed by the writer he had never done before nor has he since that time. My colleague, Professor Asaph Hall, U. S. N., will bear testimony to the zeal with which the writer prosecuted this search.

When the ephemeris had run out the writer wrote to the Doctor and informed him that his search had been unsuccessful and requested further instructions, etc. The Doctor replied: "Search the whole visible heavens from sunset till sunrise, just as you did last year,* and you may find *something*."

Clouds and the Moon permitting, the writer followed these instructions literally, for it was no unusual thing for me to begin sweeping twenty minutes after sundown and going over every portion of the heavens down into the bright morning twilight. With any other form of an instrument than that in my hands such an amount of work would have been utterly impossible. As it was a good part of the sky, near the zenith and above and below the pole, were twice swept over.

That I did not do this observing in a haphazard manner may be shown that in September of that year I picked in the northern heavens a faint nebula which had never before been recorded.

Dr. Peters' comet has not as yet been re-discovered, but there seems to be no reason why it may not be picked up at any time, and the future discoverer, if he should read these lines, will know that at least one observer made a faithful and diligent search for the long lost wanderer in space.

SLIGO, Md.,
1898, Nov. 3.

WHO DISCOVERED COMET 1862 III?

LEWIS SWIFT.

FOR POPULAR ASTRONOMY.

I have read the letters of Professors Tuttle and Hall published in the November No. of POPULAR ASTRONOMY and it only adds another weak link in the valueless chain of negative testimony. They make a great ado about the tail I say I saw but it is only another story that sounds well till the other side is heard. If the

* In 1858, the writer ir dependently detected *five* comets, between Jan. 3 and Sept. 9, three of which were original with him.

reader will read my account of the discovery of this celebrated comet he will be better prepared to follow the drift of this reply to their indirect insinuation that I have attempted to palm off on the astronomical world a fraudulent discovery. As the letters contain no facts, only insinuations about the tail, I will confine my remarks mostly to that. As there are a great variety of comets' tails I leave it to the reader to judge how much more creditable it would have been had they ascertained what kind of a tail I saw. It was of gegenschein faintness, which would have been overlooked by nine astronomers out of ten. I am willing to admit however that it may have been imaginary so faint was it but I am inclined to think it was real. That they did not see it proves nothing. When one astronomer asserts that he has seen the middle ring of Saturn divided, what right therefore has another to say it was not because he failed to see it. The same applies to the moons of Mars. I have lately seen two tails to Brooks' comet, one pointing toward the Sun the other from it. I have yet to learn if they have been seen by others. My last observation was on Nov. 4 when only one was visible, the one toward the Sun. If others do not see them am I to be confronted with the statement that it had no tail? They like the one under discussion may possibly have been imaginary but I require something stronger than negative testimony to convince me that they were spurious. When the supposed comet had been found that had just before been discovered, it was a vital point with me to prove that it was not a bright nebula, and the desired proof was a tail which after a little I considered was visible. The astronomers were interested in other matters, its place, direction and rate of motion and other data.

The ludicrous statement that my comet must have swallowed its tail before it was seen at Cambridge I treat with the silence it deserves. There is not an instance on record of a comet drawing its tail to itself. A comet's tail is formed by repulsion generally from the Sun, but sometimes toward it, and cannot change to attraction. Holmes' comet repelled its tail and disappeared from faintness by diffusion, but did not swallow it.

The only claim Professor Tuttle has is, that knowing it to be a new comet he announced it, while I three days before discovered it, and supposing it to be the fast moving comet I was searching for did not, except locally.

Maria Mitchel discovered a comet in 1847, which she did not as required announce to the King of Denmark, who had offered a gold medal for their discovery. Three days after Di Vico discov-

ered it, and having announced it, demanded the prize, and so did Miss Mitchel. The King ordered Professor Schumacher to decide who was entitled to the medal, who decided in favor of Miss Mitchel. I can even at this late day furnish affidavits that I discovered the comet three days before Tuttle did.

LOWE OBSERVATORY, Echo Mountain, Cal.,
Nov. 12, 1898.

AN ASTRONOMER'S REVERIE.*

MARY E. MITCHELL.

FOR POPULAR ASTRONOMY.

Darkness spreads over the hemisphere in the absence of the Sun, from its setting to its rising, but it is only a partial phenomenon surrounding the Earth, and in which the rest of the universe does not participate. When we are enveloped by the calm silence of a profound night, we are led to attribute to the entire universe the scene which surrounds us, as if our world were the centre and pivot of creation. A few moments of reflection suffice to show us how great is this illusion and to prepare us for the conception of the world as a whole.

It is evident, in reality, that the Sun cannot show at the same time all the sides of the same object, but only those which are turned towards it; it only shows half of the terrestrial globe at once; it follows from this that night is nothing else than the state of the part not illuminated by the Sun. If we consider the terrestrial globe suspended in the extent of space, we should understand that the side turned towards the Sun is the only side that is light, while the opposite hemisphere remains in darkness, and that this darkness presents the aspect of a cone. And further, as the Earth turns on itself, all its parts present themselves successively to the Sun and pass in order through this darkness, and it is this which constitutes the succession of days and nights for each country of the world. This simple glance is enough to show that the phenomenon to which we give the name of night belongs properly to the Earth, and that heaven, the rest of the universe is independent of it.

That is why, if at some hour of the night we should raise ourselves in thought above the terrestrial surface, we should find that far from remaining always in the night, the Sun pours its bil-

* Translated from the French by Miss Mitchell.

lows of light in space. If we should rise to one of those planets which, like the Earth, roll in the region of space where we are, we should recognize that the night of the Earth does not extend to these other worlds, and that the period which with us is consecrated to repose, does not there serve that purpose. While here all beings are sunk in the immobility of the silence of night, there the forces of nature continue the exercise of their brilliant functions, the Sun shines, life continues, movement is not suspended, and the region of light pursues its dominant action in the heavens (on the hemisphere opposite to ours) at the same hour when sleep renders immovable all the beings on the hemisphere which we inhabit.

It is very important that we know these things, to accustom ourselves to that idea of the isolation of the Earth in the midst of space, and of thinking that all the phenomena which we observe on this globe are peculiar to it, strangers to all the rest of the universe. Thousands and thousands of similar globes roll in space. One of the most fatal illusions of which it is necessary to undeceive ourselves at the first, is that the Earth appears to us as the inferior half of the universe, and the heavens as the superior half. There is nothing in the world more false. The heavens and the Earth do not make two separate creations, as we have heard again and again: they are but one. Earth is in the heavens. Heaven is an immense space of indefinite extent, distance without limit; no border circumscribes it, it has no beginning nor end, height nor depth, left nor right: it is the infinite quantity of spaces which succeed eternally in all senses. The Earth is a little globe of matter, placed in space, without support of any kind, like a ball which is held alone in the air, like those little captive ballons, which rise and float in the atmosphere when the slender cord which held them has been cut. The Earth is a star of heaven, it is a part of it, it peoples it, in company with a great number of globes similar to this, it is isolated, and all these other globes move alone in space.

This conception of the universe is not only very important, but it is a truth which is eminently necessary to fix well in the mind. Otherwise three-fourths of astronomical discoveries remain incomprehensible. Then let this first point be well understood and established in our thought. Heaven is the space which surrounds us on all sides; the Earth is a globe suspended in this space. But the Earth is not alone in this space. All the stars which scintillate in the heavens are isolated globes, each of itself a sun burning with its own light; they are at a great distance from here;

but there are stars nearer which resemble more that which we inhabit; in this sense they are not suns, but obscure earths receiving like ours the light of our Sun. These worlds, called planets are grouped into a family; ours is one of the members of this family. In the centre of this group shines our Sun, the source of the light which illumines them and of the heat which warms them. Moving in the midst of the space which surrounds it on all sides, this group is like a fleet of different ships rocked in the ocean of the heavens.

A multitude of suns, surrounded like ours by a family of which they are the sources of heat and light, move similarly in all the points of space: these suns are the stars with which the prairies of heaven are studded. In spite of the appearance caused by the perspective of distance, there are immense spaces between all these systems and ours, such distances that the highest figures of our numeration are scarcely able to number the smallest among them. A reciprocal distance, which our numbers cannot express, separate these stars one from another, extending them from depths into depths. In spite of these prodigious intervals, these suns are in number so many that their enumeration surpasses still all our means of reckoning; millions joined to millions cannot reach the number of this multitude! . . . Let the thought try, if it be possible, to represent this great number of systems and the distances which separate them from one another! Confounded and soon lost in the aspect of this infinite richness, it can only admire in silence this indescribable marvel. Raising itself without ceasing above the heavens, passing beyond the far off regions of this ocean without limits, it discovers always a new space and new worlds forever reveal themselves to its eagerness . . . . heavens succeed to heavens, spheres to spheres . . . when the deserts of space are opened to other deserts, when immensities to other immensities . . . . and this is carried on without intermission through the centuries with the rapidity of thought, the soul perpetuates its flight beyond the most inaccessible limits which the imagination can conceive, and even then the infinity of an unexplored extent remains yet open before it . . . . the infinity of space is opposed to the infinity of time, rivalling without ceasing, the one never able to exceed the other and the spirit is arrested weakened by fatigue, in the vestibule of infinite creation, as if it had not advanced at all in space.

The immensity of the heavens has been sung by many lyres; but how can the song of man express the reality? Poets have attempted it in their verses but one can feel the incompleteness of

their words to express the thoughts which arise in us at this marvellous contemplation. Am I not right then in saying that the reality is superior to fiction even from a poetic point of view, and that the contemplation of nature in its reality is a more fertile source of inspiration than the illusion of the spectacles presented to our senses?

In place of an immense night extending to the azure vault, in place of a robe embroidered with gold or of a vail adorned with shining ornaments, we are in the midst of life and of universal radiance. Night is no more than an accident, a happy accident which permits us to go beyond the limits which the day traces for us; we are like a voyager who, reposing in the shadow of a hill contemplates the bright landscape which is displayed up to the far-off horizon. Instead of immobility, and the silence of death we behold the spectacle of life in these worlds. By the light of truth the arbitrary vaults disappear and heaven opens its depths; the infinity of creation is revealed with the infinity of space, and our Earth losing the preponderance with which our pretensions have adorned it, recedes under our feet and disappears in the darkness, being lost in the midst of a multitude of similar little worlds. In the liberty of our flight we pass beyond the celestial countries and take the first sketch of the universe. It is thus that undeceiving ourselves at the first step of an ancient error too long held, we place ourselves in a good condition to study and are prepared to receive easily the new truths which Nature reveals in succession to our studious ardor.

VINELAND, N. J.

NOTE ON THE PLANET DQ.

ASAPH HALL.

FOR POPULAR ASTRONOMY

About fourteen years ago, at the invitation of Professor Peters, I visited the Litchfield Observatory of Hamilton College, and spent four days there. Professor Peters thought of printing some of his ecliptic zone catalogues of stars in Washington and wished me to see his work. This work was in excellent order, both the observations and the reductions. At that time Dr. Peters had discovered nearly forty asteroids. He had become much interested in these bodies, and told me he felt sure there was an asteroid whose orbit crossed the orbit of Mars, and said he hoped to discover it. This he failed to do, but the discovery of the planet DQ has realized Peters' wish. After the motion of this

singular planet has been well determined it would be interesting to calculate back its positions, and examine Peters' zones to see if he did not observe it. I think this could be done without much trouble, because the records are so clear and distinct.

CAMBRIDGE, MASS.,
1898, Nov. 2.

THE LEONID METEOR SHOWER.

H. C. WILSON.

Cloudy weather seems to have very generally interfered with early observations of the Leonid meteors. No reports have come to us of any number being seen until the night of Nov. 14, after the main shower had passed. Casual watching on the night of Nov. 10, while photographing the Pleiades from $8^h\ 21^m$ to $13^h\ 21^m$ at Northfield, revealed no meteors which could certainly be called Leonids. The following nights were continuously cloudy at Northfield, until about 9^h P. M. on the 14th, when the atmosphere became very clear and transparent and continued so for two days.

One observer, Mr. David E. Hadden, of Alta, Iowa, reports observations on the night of the 13th from $10^h\ 30^m$ P. M. to 1:00 A. M. In this time only one true Leonid was seen, that being at $11^h\ 50^m$ P. M. Several were observed radiating from Perseus, Cepheus and Camelopardalis.

On the morning of the 15th the sky appears to have been generally clear and quite a number of observers have sent in reports of their observations. Copies of the chart published in the last number of POPULAR ASTRONOMY, with numbers of meteor trails recorded upon them have been returned to us by Professor Herman S. Davis, Ph. D., of Columbia University Observatory, New York City, Mr. H. R. Smith, Philadelphia, Professor Glenn Culbertson, of Hanover College, Hanover, Ind., Mr. J. A. Parkhurst, Marengo, Ill., and Mr. Weston Wetherbee, Barre Centre, N. Y.

At Northfield.—The writer was occupied in guiding a long exposure photograph of the Pleiades from $9^h\ 50^m$ to $13^h\ 20^m$ and after that in obtaining two 2-hour photographs of the meteor radiant with the Brashear 6 inch camera, and so could give but little attention to the meteors.

Professor Payne began a systematic watch at 12:30 A. M. and continued until 3:45 A. M., in which time he counted 81 meteors nearly all Leonids, distributed as follows:

Time.				Number.
h	m	h	m	
12	30	1	30	17
1	30	2	00	8
2	00	2	30	12
2	30	3	00	18
3	00	3	30	16
3	30	3	45	10

Of these the paths of 14 were recorded upon a chart during the interval from 12:30 to 2:00 and 22 on another chart during the interval from 2:00 to 3:45. Eleven of those recorded on the first chart were certainly Leonids and radiate from an area about 6° in diameter, within the Sickle, whose center, as nearly as I can fix it, is in R. A. 148° and Decl. 20°.5. On the second chart nineteen Leonids are recorded, radiating from an area about 5° in diameter, the center being at R. A. 149° 6 and Decl. 21°.0. Only one meteor is recorded as starting within the radiant area. This appeared at a point one fourth of the way from γ to η Leonis and described a short path, extending not more than a degree and a half, toward the southeast.

The writer attempted to continue the charting while also guiding the photographic telescope, between 4:10 and 5:50 A. M. and succeeded in recording 16 probable Leonids on a third chart. Six of these were too far from the radiant and described too short paths to be trusted in determining the radiant. The other 10 place the radiant within a circle 3° in diameter with its center at R. A. 149°.6 and Decl. 21°.5.

The differences between the determinations of the radiant from the three charts may indicate some progressive change of position, but probably are due chiefly to errors of observation. The observers were both inexperienced in this kind of work. We have thought best to combine the three charts in one, which is reproduced in the cut, Fig. 1, accompanying this article. The meteor paths are represented by heavy continuous lines, with an arrow head on each indicating the direction of motion. The trails of the Leonids, within 45° of the radiant, are extended back to the radiant by means of dotted lines and the great majority of them meet the small circle 3° in diameter, having its center at R. A. 149°.6 and Decl. 21°.5.

Most of the Leonids were bright and of a blue color, many equalling first magnitude stars and few being fainter than fourth magnitude. They left luminous trails which remained visible to the eye for several seconds. The duration of the meteor itself was usually not more than one or two seconds. No detonation was heard at any time, although one meteor was so bright that it il-

luminated the dome where I was photographing as if a lamp had been brought suddenly into the room. The meteor itself was not seen so that I cannot tell whether it was a Leonid or not. This occurred between 11^h and 12^h when I was unable to record the time.

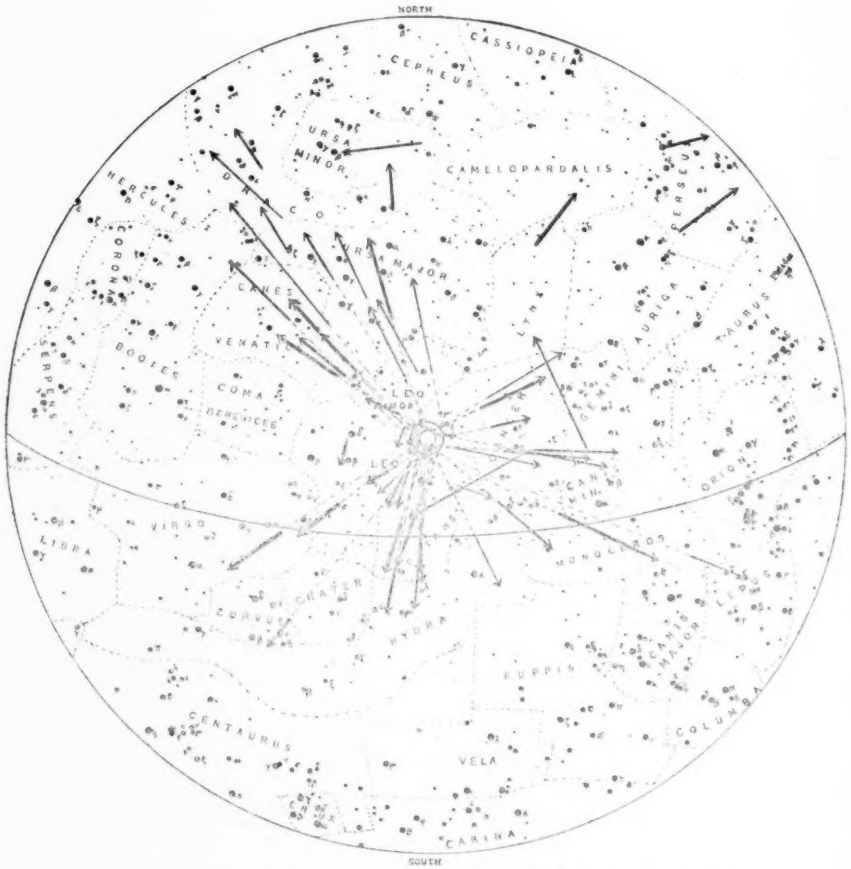


FIG. 1. CHART OF LEONID RADIANT BY PROFESSORS PAYNE AND WILSON. Northfield, Minn., Nov. 14, $18^h\ 30^m - 23^h\ 50^m$, G. M. T.

One thing that struck us as remarkable at the time was paucity of meteors near the radiant. Very few were seen within 10° of the radiant and those few were seen when Leo was near the horizon. As the radiant rose to greater altitude the distance at

which the greater number of meteors appeared increased, until between 4^h and 6^h A. M. scarcely any were seen within 20°.

The photographs were therefore disappointing. Two plates were exposed in each of the cameras one from 2^h to 4^h the other from 4^h 10^m to 5^h 50^m A. M. Central Standard Time. The Brashear 6 inch doublet carries an 8x10 plate, covering an area of the sky 10° in diameter with good definition in all parts. The 2½ inch Darlow projecting lens gives fairly good images over a circle about 20° in diameter on a 4x5 plate. One meteor trail was found upon each plate, the same being caught by both cameras. In the six inch camera picture the first trail lies to the southwest of γ Leonis and is one-third of a degree in length. It begins as a very fine line, broadens gradually for three-fourths of its length then narrows more rapidly to a vanishing line. The second trail lies about 5° to the east of ζ Leonis and is two-thirds of a degree in length. Its description is the same as that of the first. Both are perfectly straight and lines drawn through the two intersect in the east edge of the smaller circle drawn upon our chart, in R. A. 151°.5 and Decl. 22°.3. Two-thirds of a degree to the northeast of this point the trail of Chase's new comet is found upon all four plates.

On the night of the 15th watch was kept from 8:20 P. M. to 2:00 A. M., only one Leonid being seen during that time, although several were seen from other radiants.

At Columbia University Observatory, New York City.—Professor Herman S. Davis watched for meteors during the intervals of waiting between the stars in "Observations for Variation of Latitude," from 12:45 to 3:45 A. M. Nov. 15. He sends us a chart with sixteen meteor trails. Of these twelve are probably Leonids. They are nearly all on one side of the radiant and too far from it to give a good determination of position.

At Philadelphia, Pa.—Mr. H. R. Smith sends a chart with twelve long meteor trails emanating from Leo, seen on the morning of November 15. He writes: "The first meteor seen to shoot across the eastern sky was at 12:20 A. M. and from that hour until 4:30 A. M. I counted seventy-six in all. The greatest number seemed to have their radiant within the constellation Leo, and the point that would be called the center of radiation seemed about the star γ. There was one exception; at 1:25 A. M. a bright meteor came out of Ursa Major and shot in an easterly direction, disappearing in the vicinity of the Lynx. The brightness relatively to the stars was of the second magnitude and the color of the nucleus generally was similar to that of Mars, the

planet being in a position to make comparison favorable. The streaks were generally red with sometimes a bluish tinge. In several instances quite loud detonations were heard; the sounds would reach me just about the time the meteor disappeared. From 2:45 to 3:45 they seemed to reach a maximum, the largest number visible per minute within that hour being eight."

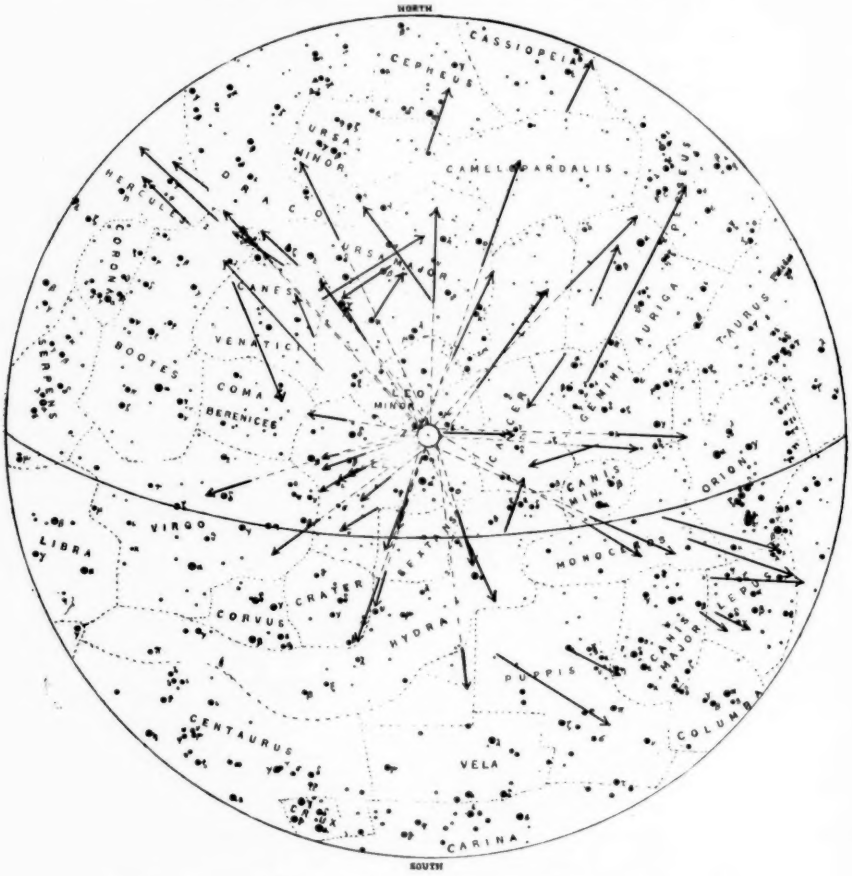


FIG. 2. CHART OF LEONID RADIANT BY PROFESSOR GLENN CULBERTSON.
Nov. 14, $18^h\ 30^m - 22^h\ 30^m$, G. M. T.

At Hanover College, Hanover, Ind.—Professor Glenn Culbertson sends us a splendid record of fifty-eight meteor trails charted on the morning of Nov. 15. We reproduce his chart in Fig. 2.

The center of the radiant area in this chart is about R. A. 149°.6, Decl. 22°.2. Professor Culbertson writes:

"I am sorry that I cannot send more, but it has been clear only Saturday morning and from 12:30 to morning of Tuesday the 15th, a most remarkable autumn for cloudiness. I enclose my own record of the meteoric paths obtained between 12:30 and 4 A. M. Tuesday, Nov. 15. It was my first work in this line, but with the exception of the first ones which I recorded I believe they are fairly accurate.

"The meteorites averaged one every three or four minutes during the time of my observations. Few if any were above first magnitude. The velocities of the Leonids were almost uniform, excepting the one almost stationary one near γ Leonis. This appeared at 2:26 Central Standard Time and moved not more than 15 or 20 minutes of arc.

"The most prominent of all that I observed was a rather slow moving one through Canes Venatici a few minutes before 4 A. M. The region of the Dipper Handle showed a greater number than any other portion of the heavens of equal area."

At Marengo, Ill.—Mr. J. A. Parkhurst photographed the radiant with a camera of 2¼ inches aperture and 8.2 inches focal length. The field covered was 21° in diameter with ζ Leonis at the center. No meteor trails were photographed although stars of the 11.5 magnitude were shown. The exposure was from 23^h 10^m to 40^m Greenwich M. T. Mr. Parkhurst sends a chart of the paths of four meteors seen in the intervals of guiding the camera. He says:

"The first clear sky was the morning of the 15th, local time. The few meteors seen were faint, 2 to 4 magnitude, swift with short trails, only one leaving a visible train. It was evident that no trails of this kind would show on the photographic plate."

At Mount Holyoke College Observatory, South Hadley, Mass.—Miss Elizabeth M. Bardwell sends the following very excellent record of the meteors counted by Prof. Keith and students of Mount Holyoke College. She says: "We saw one meteor trail that remained visible fully two and a half minutes. The train was short but broad. The spot that could be seen was about one half a degree by one-fourth degree and one end of it shifted its place as if turned by wind. We saw another which was visible about thirty seconds. The first mentioned was near δ Leonis, time 2:58, and the other in Coma Berenices, time, 4:15. The meteors were swift and quite bright. The sky was very clear."

Nov. 15.
Observations by Prof. Keith.

	Time A. M.				Leonids.	Others.
	h	m	h	m		
From	1	10	to 1	35	15	
"	1	35	to 2	00	21	2
"	2	00	to 2	10	8	
"	2	10	to 2	20	10	
"	2	20	to 2	30	8	
"	2	30	to 2	40	4	
"	2	40	to 3	00	10	5
"	3	00	to 3	15	8	2
"	3	15	to 3	30	12	3
"	3	30	to 3	45	9	1
"	3	45	to 4	00	12	
"	4	00	to 4	15	11	
"	4	15	to 4	30	9	2
"	4	30	to 4	45	3	
"	4	45	to 5	00	11	
Total in 230 minutes					151	15

Nov. 15.
By different students—three.

	Time A. M.				Leonids.	Others.
	h	m	h	m		
From	3	45	to 4	00	10	10
"	4	00	to 4	15	6	2
"	4	15	to 4	30	12	3
"	4	30	to 4	45	6	2
					All that were seen.	
"	2	00	to 2	15	14	
"	2	15	to 2	30	15	
"	2	10	to 2	20	11	
"	2	20	to 2	30	16	
Wednesday morning, Nov. 16, by three students.						
From	2	30	to 3	10	14	
"	"	"	"	"	14	
"	"	"	"	"	12	

At Carlisle, Pa.—Professor W. W. Landis, of the department of Mathematics and Astronomy at Dickinson College, writes that the shower of Leonids was observed there on the morning of Nov. 15th. The morning of the 14th was cloudy and no meteors were seen although a watch was kept from 11^h to 16^h.

Observations Nov. 14.

Time	No. of meteors seen.
h h	
11 — 12	12
12 — 13	34
13 — 14	64
14 — 14:30	54

"The number of observers was from four to twelve but circumstances prevented our keeping a watch upon the entire sky, and, following Professor H. A. Newton's estimates, I would judge the average hourly number from 100 to 125. The meteors were all small with three exceptions. Several Bielids were seen on the same evening, and a great many of the swift meteors seemed not to be Leonids. At least they did not emanate from a point anywhere near the radiant in Leo."

At Columbia, Mo.—Professor Milton Updegraff, Director of the Laws Observatory, of the University of Missouri, reports that he observed the Leonid meteors from Nov. 11 to 16, with the following results:

Astronomical Date.	Number of Leonids Observed.	Period of Watching.
Nov. 11	0	30^m
12	Sky cloudy.	
13	3	26
14	50	88
15	Sky cloudy.	
16	3	20

"Another observer here saw 12 meteors—Leonids—in 30 minutes, observing later than I did on the 13th. The same observer counted 39 Leonids in 70 minutes on the 14th."

At DesMoines, Ia.—Professor W. A. Crusinberry, of Drake University, writes the following note:

"Some members of the astronomy class and myself watched for Leonids on the mornings of Nov. 14 and 15. The highest number reported for Nov. 14 was 10. This number I counted, watching from 1:30 A. M. to 6:00 A. M. The highest number reported for Nov. 15 was 20. Two observers, respectively, counted 19 and 20. On this morning between 5 and 5:30 A. M. four very bright meteors were observed, three of them issuing from the radiant almost simultaneously. Two of them remained bright, showing a disk, until they disappeared below the horizon. In each of the two latter cases there was a bright train, reaching from the horizon to the radiant in Leo.

"For a few days before Nov. 14 the weather was cloudy here. Students made observations after Nov. 15 but no meteors were reported."

At Alta, Ia.—Mr. David E. Hadden writes:

"On the night of the 14th I commenced watching at 11:10 P. M. and at 11:22 witnessed one of the largest and most brilliant meteors I have seen in many years. It fell from a point 5° east of Polaris downward, disappearing at about R. A. 14^h 30^m; Decl. + 55°, occupying about three or four seconds in its flight. It was of an intense bluish white color, quite dazzling to the eyes and before disappearing a slightly reddish hue with only a few sparks at the moment of explosion. It left no visible train. As I was observing from an octagon tower, with windows, in my residence, and being indoors, I did not clearly hear the report it made about 5 to 8 minutes afterwards, but recollect a low rumbling sound, which I did not at the time connect with the meteor. I learned next day from our town night watchman, who observed the flash indoors, that he heard a rumbling sound like distant thunder fully 8 or 10 minutes after the flash.

"At 11:46 P. M. a very long Leonid was observed moving slowly, leaving a train visible for 12 to 15 seconds. Observations ceased at 12:45 A. M. Our night watchman said he saw a large number of shooting stars in the eastern skies about 4:00 A. M. of the 15th."

At Barre Center, N. Y.—Mr. Weston Wetherbee sends the chart, which we reproduce as Fig. 3, of 22 meteors seen by him on the morning of Nov. 17 from 1:45 to 2:50 A. M. Twelve of the

meteors charted may be considered as true Leonids, with their radiant in a circle 4° in diameter, its center being in R. A. 149°.5 and Decl. 20°.9.

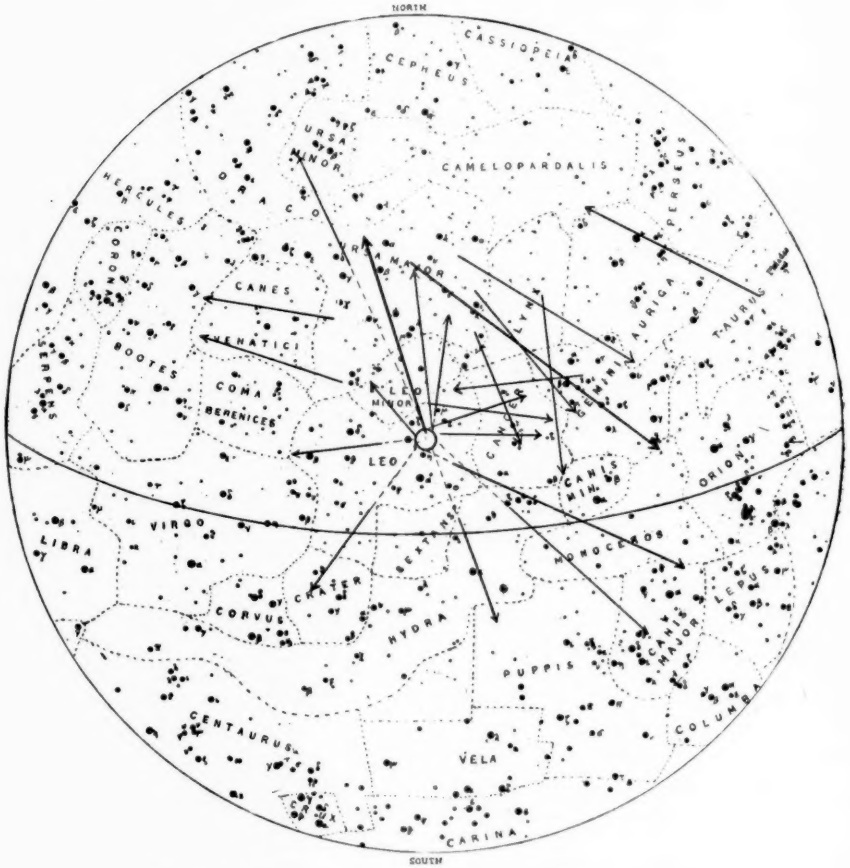


FIG. 3. CHART OF LEONID RADIANT BY WESTON WETHERBEE.
Barre Center, N. Y., Nov. 16, $18^h\ 45^m$ — $19^h\ 50^m$, G. M. T.

"These observations were made without any assistance, and to some disadvantage, and doubtless many escaped my notice. My attention was fixed on the radiant point, which enabled me to determine with some exactness those issuing from that quarter. Their motion was generally very rapid, the larger ones leaving a fiery train behind for some seconds of time. I have

tried to indicate their magnitudes, by the double markings for brightness, etc. I counted 22 meteors during this brief interval of time."

At Minneapolis, Minn.—Professor F. P. Leavenworth, Director of the Observatory of the University of Minnesota, gives the following report of observations by his students, B. L. Newkirk and Alfred Gunderson:

"Nov. 12 and 13 were cloudy, Nov. 14 fairly good and clear. No meteors were seen before 11^h. The general method of observation was according to Pickering's scheme, i. e., starting at the even hour observe time it takes to count 10 meteors, within a radius of 25° from the radiant. No other meteors were counted. This was done every half hour, only they came so slowly that a less number was counted. In addition, between times, the position and times of other meteors, especially toward the south, were observed. The following is the count of meteors in an area of 25° radius every half hour."

Central Standard Time.				No. of Meteors within 25° of Radiant.
h	m	h	m	
11	7	— 11	20	0
11	36	— 11	42	0
12	4	— 12	14	2
12	30	— 12	40	2
13	0	— 13	12	10
13	33	— 13	43	2
14	3	— 14	13	5
14	31	— 14	41	4
15	0	— 15	10	4

SOME CONCLUSIONS.

From these reports it would seem that the shower as seen in the United States was rather poorer than was expected. The maximum occurred evidently on the 14th as was predicted, and reports from the other side of the globe may yet give an account of a great shower. It is difficult to form an estimate of the average hourly number of Leonids seen on the morning of the 15th for some of the observers appear to have included in their count meteors from other radiants near Leo. The number of true Leonids seen by one observer, giving his whole time to the count, was probably somewhere about 40 per hour. This shows a marked increase over the showers of the previous years, the hourly averages being as follows:

	Date	Hourly No. of Leonids seen by one observer.
1895	Nov. 13	4
1896	14	10
1897	13	2
1898	14	40

The determinations of the radiant are fairly good considering the inexperience of the observers. The majority of the meteor trails when traced back may be made to pass through an area 5° or 6° in diameter lying wholly within the curve of the Sickle. The following is a summary of the approximate determinations of the center of this area from the charts at hand.

Date.	Observer.	Greenwich M. T.				No. of Trails.	Center of Radiant.	
		h	m	h	m		R. A. °	Decl. °
Nov. 14	Davis	17	45	— 20	45	9	151	22
14	Smith	17	20	— 21	30	12	150	20
14	Culbertson	18	30	— 22	30	30	149.6	22.2
14	Payne	18	15	— 20	00	11	148.0	20.5
14	Payne	20	00	— 21	45	19	149.6	20.9
14	Wilson	22	20	— 23	45	16	149.6	21.5
14	Parkhurst	23	10	— 23	40	3	150.0	20.2
16	Wetherbee	18	45	— 19	50	12	149.5	20.9
						Average	149.7	21.0

This places the radiant about a degree and a half south of the average position as determined during the past 65 years.

A considerable number of the meteors, which had the same appearance as the indisputable Leonids, pursued courses so nearly like the latter that one would naturally conclude that they were from the same source. Yet their trails when extended backward cannot by any reasonable supposition of error be made to pass through the limited area marked by the majority of the meteors. Some of the observations by the more reliable observers indicate that the radiant covers at least the whole of the Sickle in the fore part of Leo.

PLANET NOTES FOR DECEMBER.

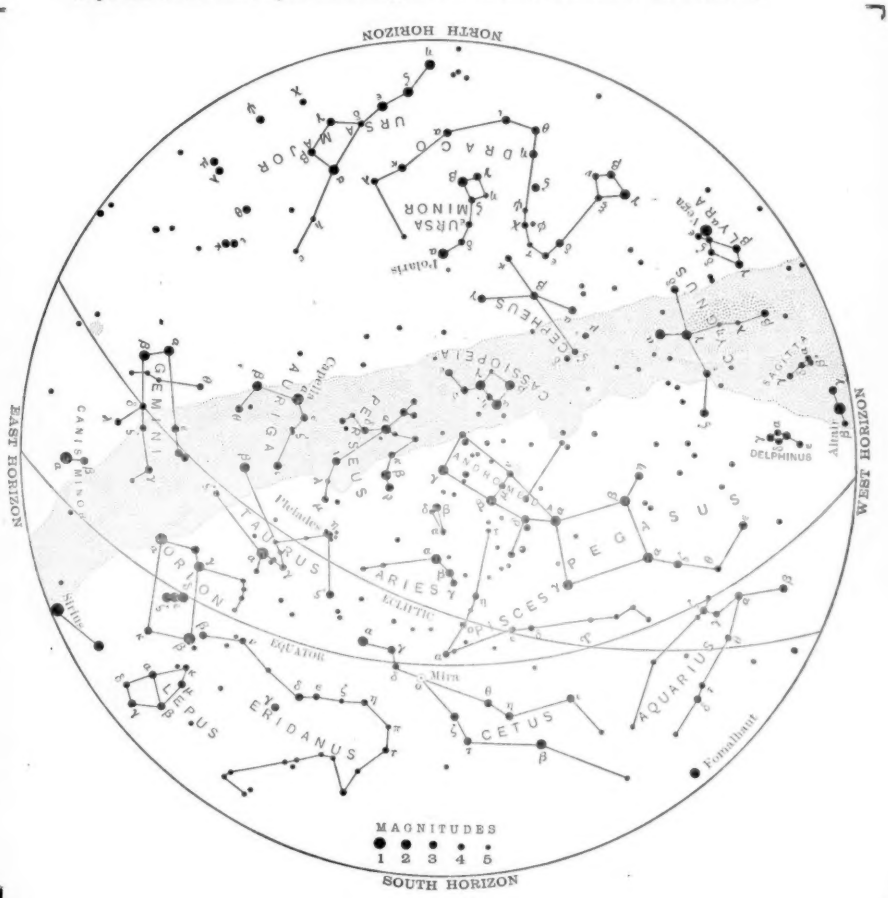
H. C. WILSON.

Mercury will be at greatest eastern elongation, 21° 10′ east from the Sun, on Dec. 3 and will be visible toward the southwest about an hour after sunset during the first week of the month. On the 21st Mercury will pass between the Earth and Sun, being at inferior conjunction at about 4 P. M., Central Standard time. Mercury will then be about two and a half degrees north of the Sun's center.

Venus will pass between the Earth and Sun on Dec. 1, being at inferior conjunction about 11 A. M. Venus will then be a little over a degree south of the Sun's center. A few days later Venus will become visible as "morning star," seen toward the southeast just before sunrise. Venus and the waning Moon will be in conjunction on the morning of Nov. 12.

Mars is now a conspicuous object in the east after 9^h P. M. The planet will be stationary in Cancer on the 10th and after that will move northwest toward

the Gemini. Mars is now about 77,000,000 miles from the Earth and its disc is 12″ in diameter. At the end of the month the disc will be 15″ in diameter. The meridian altitude of the planet will be high all this winter and it would be a fine time for the study of the surface were it not for the winter temperature which always has a bad effect upon the seeing as well as the condition of the observer.



THE CONSTELLATIONS AT 9 P. M., DECEMBER 1, 1898.

Jupiter is to be seen toward the southeast, in the morning after 3 o'clock in the constellation Virgo east of the star Spica. The colors of Jupiter and Spica are almost exactly the same, but the planet is much the more brilliant of the two. Jupiter's disc is now 30″ in diameter, increasing to 32″ at the end of the month.

Saturn will be in conjunction with the Sun on Dec 6 and so cannot be seen this month.

Uranus **is near Saturn and also in unfavorable position for observation.**

Neptune **will be at opposition on the 14th, and so can be observed during the whole of the night. It is in Taurus a little less than 1° north of the star ζ in the tip of the Bull's horn.**

A ***Partial Eclipse of the Sun****, Dec.* 13, will be visible only upon the waters of the southern ocean. The eclipse is hardly worth mentioning since the umbra of the Moon's shadow will not touch the earth at all and at the maximum only one forty-fourth of the Sun's diameter will be hidden by the Moon.

A ***Total Eclipse of the Moon****, Dec.* 27 will be visible generally in North and South America, Europe, Asia and Africa. In America the Moon will rise eclipsed.

ELEMENTS OF THE ECLIPSE.

Greenwich Mean Time of conjunction in right ascension, December 27 $11^h\ 37^m\ 52^s.0$.

Sun's right ascension	$18^h\ 27^m\ 29^s.45$	Hourly motion	$11^s.08$
Moon's right ascension	6 27 29 .45	Hourly motion	128 .63
Sun's declination	23° 18′ 7″.5 S.	Hourly motion	0′ 7″.3 N.
Moon's declination	23 30 53 .2 N.	Hourly motion	4 9 .4 S.
Sun's equa. hor. parallax	8.9	Sun's true semi-diam.	16 16.1
Moon's equa. hor. parallax	54 6.4	Moon's " "	14 43.9

TIMES OF THE PHASES.

	Gr. M. T.	Central Time
Moon enters penumbra Dec. 27	8 32.9	2 32.9 P. M.
Moon enters shadow	9 47.5	3 47.5 "
Total eclipse begins	10 57.5	4 57.5 "
Middle of eclipse	11 42.1	5 42.1 "
Total eclipse ends	12 26.7	6 26.7 "
Moon leaves shadow	13 36.4	7 36.4 "
Moon leaves penumbra	14 50.7	8 50.7 "

Magnitude of the eclipse = 1.384 (Moon's diameter = 1.0)

The Moon.

	Phases.	Rises. (Central Standard time at Northfield; Local Time 13m less)	Sets.
		h m	h m
Dec. 6	Last Quarter	17 49 P. M.	12 20 P. M.
13	New Moon	8 3 A. M.	4 46 "
19	First Quarter	11 38 A. M.	12 28 A. M.
27	Full Moon	4 28 P. M.	8 20 "

Occultations Visible at Washington.

Date 1898.	Star's Name.	Magnitude.	IMMERSION. Washington M. T. h m	IMMERSION. Angle from N pt. °	EMERSION. Washington M. T. h m	EMERSION. Angle from N pt. °	Duration. h m
Dec. 1	B. A. C. 2658	7.2	18 40	122	19 49	290	1 9
24	33 Tauri	6 3	5 36	113	6 31	210	0 55
25	103 Tauri	6 0	16 23	125	17 15	250	0 52
26	2 Geminorum	7.2	18 57	73	19 42	309	0 45

VARIABLE STARS.

J. A. PARKHURST.

Minima of the Variable Stars of the Algol Type.

[Given to the nearest hour in Greenwich Mean Time.]

1899.

U CEPHEI.

	d	h
Jan.	3	11
	5	22
	8	10
	10	22
	13	10
	15	22
	18	10
	20	21
	23	9
	25	21
	28	9
	30	21

ALGOL.

	d	h
Jan.	2	7
	10	22
	13	18
	16	15
	19	12
	22	9
	25	6

λ TAURI.

	d	h
Jan.	1	8
	5	7
	9	6

S CANCRI.

	d	h
Jan.	3	10
	12	22
	22	10
	31	21

S VELORUM.

	d	h
Jan.	4	5
	27	23

δ LIBRÆ.

	d	h
Jan.	2	18
	9	18
	16	17

δ LIBRÆ Con.

	d	h
	23	17
	30	16

U CORONÆ.

	d	h
Jan.	7	18
	14	15
	25	0

W DELPHINI.

	d	h
Jan.	10	6
	24	16
	29	11

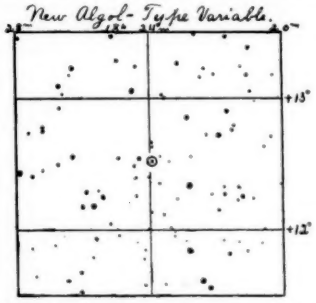
Y CYGNI.

Odd min.

	d	h
Jan.	1	9

$2P = 2^d\ 23^h\ 54^m.5$

Y CYGNI. Only the odd minima are visible, and these only in European longitudes. It cannot be observed in the United States till late next fall.



NEW ALGOL TYPE VARIABLE. Mr. Edwin F. Sawyer announces that the star DM. + 12°,3557 is a variable of the Algol type, with a period of $21^h\ 21^m$ and a range of variation of from 7.0 to 7 5 magnitude. The epoch of minimum is Oct. 3, $13^h\ 1^m$, Greenwich Time. The place of the star is

R. A.	$18^h\ 23^m\ 56^s$,	
	26 1	
Decl. + 12°	31′.0,	(1855)
	32 .6	(1900)

The star is so far west that only a few minima can be observed in December early in the evening. Nine periods are equal to $8^d\ 0^h\ 9^m$, so that every eighth evening the minimum occurs nearly at the same time. The following minima are all that can be observed this season:

Epoch.	Gr. Time.	Epoch,	Gr. Time.
63	Nov. $28^d\ 14^h$	82	Dec. $15^d\ 12^h$
64	29 11	90	22 15
72	Dec. 6 14	91	23 12
73	7 12	100	31 12
81	14 14		

The accompanying chart, from the Durchmusterung, will serve to identify the variable, which is one hour following α Ophiuchi, and in a region singularly barren of naked eye stars.

HAGEN'S ATLAS OF VARIABLE STARS. *Astronomische Nachrichten* No. 3523 and *Astrophysical Journal*, October 1898, each contains a specimen chart from this new Atlas. The chart selected is that for 2857 U Puppis, one of the first series, which contains about 50 telescopic variables from the equator to south declination 25°. The chart, covering one square degree, is about six inches square, the scale being 1 mm. = 23″.2. The specimen is nicely executed and the Atlas will be of great value to observers of variable stars. The price for the series of 50 charts, with catalogue, is 1.20 Marks per chart. The publisher is Felix L. Dames, Berlin W, Landgrafenstrasse 12.

NEW EDITION OF THE DM. CHARTS. It was reported at the Harvard Conference that satisfactory progress was being made in the printing of these charts. The subscriptions from America were quite numerous.

PHOTOGRAPHIC MAGNITUDES OF VARIABLES. On page 473 of the October number was given a short notice of the method used at the Von Kuffner Observatory, Vienna, for determining the photographic magnitudes of variables. A full description of the method has since been published in Vol. V of the Publications of the Von Kuffner Observatory. Some details may be of interest.

The instrument used in the experiments was a photographic refractor of 156 mm. aperture and 294 cm. focal length. The photographic plate was placed 28 cm. within the focus of the objective, in which plane the stellar image was enlarged to a disk 1.5 mm. (or 1′.6) in diameter, consisting of a central image surrounded by two concentric diffraction rings, the width of these rings being about one tenth the diameter of the disk. The area between the rings was faintly illuminated. The effect of thus weakening the light by spreading it over a disk, was that an exposure of 30^m was required to give a measurable image of an 8th magnitude star, and 90^m for a 9th magnitude star. The plates used were Schleussner, gelatine emulsion, and they were developed for five minutes in Rodinal, diluted in the proportion of 1 to 20. The interesting part of the method is the preparation and use of the comparison scale. This consisted of the images formed by a series of exposures on the same plate, of the star δ Persei, the exposure time, t, being determined by the expression, $t = 3^s \times \left(\frac{4}{3}\right)^k$, in which k was given the values, 0, 1, 2, etc. to 16. The time therefore varied between 3^s and 5^m. The scale plate and the plate to be measured were placed with their film sides together and examined by transmitted light. The star image to be measured was placed between the scale images between which it seemed to lie in blackness, as estimated with the naked eye, and its position in tenths of a scale interval, was estimated with the aid of a low power lens. Repeated trials showed that remarkable accuracy was attainable by this method, in a long series of measures the greatest difference in the estimates of a single star being 0.25 magnitude, and the probable error of a single comparison being only 0.04 magnitude.

The special advantage of this method (in contrast to the usual one of measuring the diameters of the focal images) was found to lie in the fact that *the images formed were not noticeably affected by the condition of the seeing.* As a test of this, ten exposures were made on the Pleiades, in widely different conditions of the atmosphere. When these plates were reduced it was found that the average deviation between the single measures and the mean, for 30 stars, was only 0.05 magnitude, and no single difference was greater than 0.20 magnitude. Thus the most troublesome and unmanageable source of error in the determination of photographic magnitudes, seems to have been overcome.

COMET NOTES.

New Comet *j* 1898 (discovered photographically by Chase.)—A new comet was found on the photographic plates exposed by Dr. Chase, of Yale Observatory for the purpose of determining the radiant point of the Leonid meteors on Nov. 14. It was found upon five plates taken at Yale, also upon two plates taken at Harvard College Observatory and four at Goodsell Observatory. Probably it was photographed at other places also, but these are the only reports at hand. The comet is easily seen upon the plates when once pointed out but is exceedingly faint in the telescope. Its position on the discovery plate was

Greenwich M. T.	R. A.	Decl.
Nov. 14 $17^h.5$	$10^h\ 07^m\ 04^s$	$+22°\ 55'$

Daily motion in R. A. $+1^m.6$; in Decl. $+4'.4$.

It was observed by Wilson with the 16-inch telescope at Northfield on the morning of November 26 and at Lick Observatory by Coddington on the mornings of November 24, 25 and 26. The discovery position was within 1° of the radiant point of the Leonid meteors and it will be interesting to determine whether it has any connection with those bodies or not.

Elements of Comet *j* 1898 (Chase.)—The following elements and ephemeris of the new comet have been telegraphed to us from Harvard College Observatory. They were computed by Messrs. Coddington and Palmer of Lick Observatory from the observations Nov. 24, 25 and 26. They indicate the comet is on the way to perihelion and is likely to become much brighter.

ELEMENTS.

$T =$ April 10.65 Greenwich M. T.
$\omega = 136°\ 16'$
$\Omega = 107\ \ 11$
$i = \ 33\ \ 42$
$q = 0.6821$

EPHEMERIS.

Date.	α h m s	δ ° ′	Brightness.
Dec. 1	10 33 00	+ 24 19	1.00
5	10 39 16	+ 24 48	
9	10 45 20	+ 25 23	
13	10 52 20	+ 26 03	1.61

Photographs of the New Comet *j* 1898 (Chase).—The accompanying cuts (see Frontispiece) are reproduced from enlargements of two negatives exposed in the Brashear 6 inch camera on the night of November 14, by H. C. Wilson. The original plates are 8x10 inches and cover an area of sky about 12° in diameter. The star ζ Leonis was at the center of each plate. The first was exposed from 2:10 A. M. to 4 A. M. and the second from 4:10 A. M. to 5:50 A. M. Central standard time. The camera was not guided very carefully, for the observer was at the same time watching for meteors, so that the star images are not perfectly round.

The enlargements were taken from near the centers of the plates and are on a scale of approximately 3.6 times that of the originals, and 1 millimeter equals approximately 60″. The comet is shown as a short smudgy streak beneath one of the star images near the center of the picture. It is a little to the left of the star in the first picture and to the right of it in the second, so that its motion during the four hours' exposure is quite noticeable.

In these pictures we have reproduced the negatives instead of prints from them, and the stars appear as black spots instead of white. The star nearest the comet and just above it is DM. 23°, 2189 and is of the 9.1 magnitude. The two below and to the left of this, of nearly the same size, are DM. 23°, 2186 and DM. 22° 2191. Their positions for 1855 are

		Magnitude.	R. A.	Decl.
	°		h m s	° ′
Dm.	22 2191	8.6	10 4 16.8	+ 21 55.9
	23 2186	8.8	10 4 20.9	+ 23 4.9
	23 2189	9.1	10 4 48.9	+ 28 9.8

Ephemeris of Wolf's Comet.

1898.		α			δ		log *r*	log Δ	Ab.-Z.		Brightness.
		h	m	s	°	′			m	s	
Dec.	1	7	1	49	− 14	29.1					
	2		1	9	14	40.5	0.3341	0.1453	11	36	2.37
	3	7	0	26	14	51.5					
	4	6	59	42	15	2.2	0.3364	0.1457	11	36	2.34
	5		58	56	15	12.4					
	6		58	10	15	22.3	0.3387	0.1464	11	37	2.31
	7		57	23	15	31.7					
	8		56	34	15	40.7	0.3411	0.1472	11	39	2.28
	9		55	43	15	49.2					
	10		54	52	15	57.3	0.3434	0.1483	11	41	2.24
	11		53	59	16	5.0					
	12		53	5	16	12.3	0.3457	0.1496	11	43	2.20
	13		52	10	16	18.9					
	14		51	15	16	25.2	0.3480	0.1512	11	45	2.16
	15		50	19	16	31.0					
	16		49	22	16	36.4	0.3503	0.1529	11	48	2.12
	17		48	25	16	41.3					
	18		47	28	16	45.8	0.3526	0.1549	11	51	2.08
	19		46	29	16	49.7					
	20		45	31	16	53.2	0.3549	0.1571	11	55	2.04
	21		44	32	16	56.2					
	22		43	32	16	58.8	0.3572	0.1596	11	59	1.99
	23		42	33	7	0.9					
	24		41	34	17	2.6	0.3594	0.1622	12	3	1.95
	25		40	35	17	3.8					
	26		39	36	17	4.5	0.3617	0.1651	12	8	1.90
	27		38	37	17	4.6					
	28		37	38	17	4.6	0.3640	0.1682	12	13	1.85
	29		36	40	17	3.9					
	30		35	43	17	3.1	0.3662	0.1715	12	19	1.80
	31	6	34	46	− 17	1.7					

Ephemeris of Planet 1898 DQ.

1898		α app			δ app.		log. *r*	log. Δ
		h	m	s	°	′		
Dec.	1	21	45	30	− 1	44.2		
	3		49	17	1	27.0		
	5		53	8	1	9.3		
	7	21	57	3	0	51.0	0.1782	0.1508
	9	22	1	2	0	32.2		
	11		5	5	− 0	12.8		
	13		9	11	+ 0	7.1		
	15		13	21	0	27.5	0.1708	0.1641
	17		17	34	0	48.5		
	19		21	51	1	9.9		
	21		26	11	1	31.8		
	23		30	35	1	54.2	0.1632	0.1757
	25		35	2	2	17.0		
	27		39	32	2	40.3		
	29		44	5	3	4.0		
	31	22	48	40	+ 3	28.2	0.1552	0.1859

GENERAL NOTES.

This number ends volume six and a large number of subscriptions expire at this time. If the publication is desired please order renewal promptly.

It is hoped that all subscribers will notice that hereafter volumes of ten numbers each will be issued annually. No numbers will be published for July and September.

Comet 1862, II.—In the November number of POPULAR ASTRONOMY, Mr. H. P. Tuttle has a note regarding priority of discovery of this comet.

As I had something to do in establishing Mr. Swift's claim, a brief statement in regard to its discovery may be of interest.

The comet was discovered by Mr. H. P. Tuttle at the Harvard Observatory, on the night of July 18, 1862, and on the same night about one hour later it was independently discovered by Mr. Thomas Simons, my assistant at the Dudley Observatory. I announced the discovery the next day, and made an observation for position with the equatorial on the night of discovery.

Some days later I received a letter from Mr. Swift stating that he had seen a comet on the 15th, which at the time he supposed was another comet, which was located near the same region.

At my request Mr. Swift sent me a diagram of the comet and the stars in the field of his telescope; together with the diameter of the field. I identified one or more stars and an ephemeris showed the comet to have been in the place indicated by Mr. Swift's diagram.

I sent a note regarding Mr. Swift's observation to the *Astronomische Nachrichten*.

In the *Monthly Notices* of the Royal Astronomical Society, Vol. XXIII, No. 4, in the summary of discoveries p. 1862, is the following:

"The second (comet) appears to have been seen at Marathon, U. S., by an amateur astronomer, Mr. Swift, as early as July 15; three days afterwards it was found by Mr. Tuttle, at Harvard College, Mass., and on the 22d was perceived at the Observatory of the Museum of Florence, by Mr. Touissant."

I think Mr. Swift is mistaken with regard to a tail at the time of discovery.

G. W. HOUGH.

DEARBORN OBSERVATORY, Northwestern University.
Nov. 7, 1898.

The Companion to β Orionis ($= \beta$ 555.)—I have recently secured the following measures of the close double situated 9½″ from Rigel in position angle 202°:

Date	θ	ρ_0	Eyepiece	Seeing	
1898.794	175°.3	0″.18	1500	4	36-inch
.878	181 .0	0 .13	1500	3	"

The star was examined on three other fairly good nights but, though elongation was suspected the seeing was not good enough to make reliable measures.

These results derive their interest from the previous history of the pair. In 1878, Professor Burnham, who had long suspected the star to be double, was able to measure it with the 18½ telescope of the Dearborn Observatory, the mean of two complete observations being

1878.16 179°.0 0″.35

an additional measure, of angle only, reading 160°.3. The measures of distance, the observer says, "more properly represent the longer diameter of the star. The true central distance is certainly less than 0″.2."

Other observers, with instruments of various sizes, failed to detect any elongation (except Mr. Herbert Sadler, who had independently suspected the star's duplicity) and Burnham himself writes in 1882:

"1881.151 Possibly elongated, but doubtful.

This star was examined many times in 1880, 1881 and 1882, with similar results."

In 1889, 1890 and 1891, he repeatedly examined the star with the 36-inch refractor of this Observatory, always finding it single, and came to the conclusion "it may not be double after all, but should be watched for a few years longer."

Professor Burnham recently called my attention to the star by asking me "to see if the 10″ companion to β Orionis is double." The result I have given above. Unless my measures are entirely at fault, the star must be in rapid motion, for an elongation even half as great as that now visible would have been detected in 1889-91 without fail.

It may be well to add that in making my measures the bright star was occulted to prevent its position from influencing the settings, and that at the time of making the first measure I had entirely forgotten the previous history of the star.

R. G. AITKEN.

LICK OBSERVATORY, University of California, Nov. 22, 1898.

Brilliant Meteor.—The writer saw at this place on Nov. 7th, 5:07 P. M., 75th Meridian time, one of the grandest, but strange and beautiful of meteoric phenomena. While yet in full daylight a large meteor was seen to emerge from the southeastern sky in the neighborhood of "Zeta," Ceti. Its flight was southwesterly when it disappeared from view. In less than one degree from its place of disappearance it instantly broke out again with great splendor, traveling some three degrees when it burst, leaving behind a full degree of fragments, which were a beautiful red, while the parent mass was a lovely sea green. It disappeared in Pisces Australis and was visible some two seconds of time. The morning sky here has been very unfavorable for observing the Leonids, but on the morning of the 15th, at about 5:00 A. M. through the broken clouds, a large meteor was seen to emanate from the zenith, very near the radiant point and cross the sky very rapidly in a south of westerly direction. It vanished near the horizon in Orion.

WESTON WETHERBEE.

Barre Centre, N. Y.,
Nov. 16th, 1898.

Observations of the Maximum of Mira (o Ceti) 1898.—As the sky clouded nightly for several successive weeks, satisfactory observations were not obtained of the variable star Mira until the 9th of September, since which date 46 naked eye estimates of its comparative brightness were made, a telescope and opera glass being also used in cases of uncertainty.

The observations on the following dates are sufficient to convey the general result.

Sept. 9th 1:30 A. M. The variable not being too far from the meridian for a correct estimate it was seen to be equal to Gamma Ceti.

" 18th 11:00 P. M. Brighter than Gamma.

" 22d 11:00 P. M. Midway between the brightness of gamma and alpha Ceti.

" 28th 10:30 P. M. One-fourth less than alpha.
" 30th. Near midnight, when the two stars were of equal altitude, and the sky particularly clear, the same estimate was made. They were then between 20° and 30° east of the meridian. The nearly full Moon about 40° west of Mira and still further from the comparison star scarcely interfered with the accuracy of the estimate as both stars are of the same hue.
Oct. 2d 10:00 P. M. Far in the southeast they seem alike in tint and brightness.
" 4th 2:00 A. M. They are near the meridian and though the altitude of Mira is lower, it seems fully equal to Alpha. This is the first time in five years that the variable has equalled this bright orb of 3d magnitude.
" 5th 10:00 P. M. Mira seems a shade dimmer than Alpha, what might be classed as 2/10 or perhaps less.
" 12th 4:30 A. M. Ditto. Mira had an altitude about 22° lower than the comparison star.
" 16th 10:30 P. M. Ditto with equal altitudes on a clear dark sky.
" 18th 4:00 A. M. Ditto.
" 19th 10:00 P. M. The difference seems to have increased.
" 25th. It is one-fourth dimmer than Alpha.
" 27th. One-third dimmer than Alpha.
Nov. 1st. Midway between alpha and Gamma Ceti.
" 8th. It seems nearer to the size of Gamma.
" 11th. One-fourth brighter than Gamma.
" 15th. Equal to Gamma.
" 21st. In hazy moonlight the variable seems very slightly dimmer than Gamma.

SAN FRANCISCO, Nov. 23rd. ROSE O'HALLORAN.

SS Cygni.—On its late appearance my observations of SS Cygni are as follows:

1898 Sept. 4	Suspected.	1898 Sept. 12	Cloudy.
5	8.35 Mag.	13	8. 1 Mag.
6	Cloudy.	14	Seems fainter.
7	8.25 "	15	8. 2 "
8	8.15 "	16	Cloudy.
9	8.15 "	17	8.95 "
10	Cloudy.	18	9.67 "
11	"		

The star owing to cloudy weather was not visible last night and I do not expect to see it tonight.

Mira has reached one maximum 3d magnitude and is at a stand since the 15th. If this proves to be the principal magnitude this year then the star will be only fifteen days late this appearance as maximum on terms of the second catalogue was due 30th August last. DAVID FLANERY.

Memphis, Tenn., Sept. 20, 1898.

Coast Survey Star Catalogue.—The Coast and Geodetic Survey has made computations of the mean north polar distances of all stars observed for latitude with a zenith telescope by its observers. The accumulated results of such computations have now become so valuable that it is proposed to publish them in the near future in the form of a star catalogue.

At first the methods of computation were comparatively crude, the number of catalogues used was small, and no systematic corrections were applied. The computations now made are based upon fifty catalogues covering the period 1755-1895, systematic corrections are applied to each catalogue, and both the north polar distance and proper motion together with their probable errors and the epoch of greatest weight are derived from a least square adjustment. The weights assigned to the separate catalogues, and the systematic corrections, are those given by Professor Boss in the Report of the Northern Boundary Commission, for the catalogues there investigated. For other catalogues the systematic corrections and weights have been derived by special investigations so as to conform to the Boss system, which is the system upon which the places of the American Ephemeris depend.

The results of the computations now at hand will when published make a catalogue of about 3,500 stars for about one-half of which the most refined computations of north polar distance have been made. For the remainder the computations are of varying degrees of accuracy depending upon the date at which they were made. J. F. H.

The Brashear 18-inch Telescope of Flower Observatory.—In *Science* for Oct. 7, page 449, is found an excellent report by M. B. Snyder, of Philadelphia, of the Astrophysical conference held at Harvard College Observatory, August, 1898. In this report reference is made to the double-star work done by Eric Doolittle, using the 18-inch refractor by Brashear and Warner and Swasey.

It is said that "the difficult pairs observed are a fair test of the performance of the instrument. The theoretical power of separation is 0″.275, and yet in one case a pair was separated by 0″.24 has been measured. Comparing the work of the Brashear instrument with similar observations made by Mr. Burnham with the Clark instrument at Evanston of approximately the same aperture, it is found that the Brashear instrument will resolve all pairs shown by the Clark. Fourteen pairs of new doubles have been picked up and this indicates that an ample harvest is yet to be reaped. Four hundred and fifty pairs have been measured on three different evenings, and the results will soon be published."

Professor G W. Hough, who is Director of the Dearborn Observatory at Evanston which contains the Clark telescope before referred to, said the results certainly showed that the Brashear glass was a good one.

In figuring the separating power of the Flower Observatory glass, the Dawes' formula could not have been used, for that would give for an 18-inch glass a separating power nearly equal to 0″.253; yet, the ability to divide and measure a double whose components are only 0″.24 apart, is indeed out-doing theory as given by Mr. Dawes.

We were interested in this report which gives something definite about the quality of this new telescope for it is so much like the 16.2-inch refractor of Goodsell Observatory by the same makers which has been put on record years ago in regard to its defining power.

In *Astronomy and Astro-Physics*, Vol. 12, 1893, page 112, will be found a report of the measures of double star Σ 2145 by H. C. Wilson, and E. E. Barnard, then of Lick Observatory.

Resignation of President Kellogg of the University of California.—A San Francisco paper of recent date contains an item announcing the resignation of President Kellogg of the State University of California. For some time past a feeling has been apparent in the minds of some members of the Board of Regents that positions in the University should be given to scholars residing in

California or at least to those who reside in the Coast region. This feeling was observed in the late troubles at Lick Observatory, Mount Hamilton, at the time of the election of the present Director of the Observatory, and its influence was felt to a considerable degree, although it was not strong enough to defeat the present incumbent. This view of patronage in the lines of scholarship is wholly wrong in principle. It has the appearance of political jobbery. Just as soon as a great educational or scientific institution or professional office becomes the football of politicians the high grade of usefulness belonging to such lines of work is doomed to inferior place, and will surely in time, seek its level.

This is saying nothing against the noble scholarship of men in California. When unquestionably worthy home talent should be recognized. But a great University or a great Observatory ought to be larger in its best needs than the available scholarship of a single state. The great institutions of this country and those abroad will furnish ample evidence against anything like provincialism.

Phenomenon yet Unexplained.—I am daily a witness of a sunset phenomenon, the cause of which am unable to explain. Nowhere else have I seen the same except in southern California, where everything except telegraph poles are unlike what they are in the East.

The following is a brief description of it as seen from the Lowe Observatory, Echo Mountain, 3,700 feet above the Pacific Ocean, which, though 35 miles distant, is in plain sight except when the San Gabriel valley is filled with a peculiar kind of haze, also unlike what is seen elsewhere. It seldom, if ever, reaches to this altitude, and never interferes with celestial work at night to any great extent. But few people, I imagine, ever consider the work that atmospheric dust performs in the world's toil. If the atmosphere was absolutely free from dust, not a fog or a cloud would form, nor a drop of rain would fall. I am inclined to think that shooting stars have something to do with the formation of dust that exists in very high altitudes, which often interferes with telescopic definition.

At every sunset, when the sky is clear, which it almost always is, about 15 minutes before he sinks below a range of hills, the entire surface of the valley south of an east and west line, assumes a dark blue, which moves east as the Sun descends, slowly ascending up to the horizon, causing the sky to assume the same dark blue, which extends 90° in azimuth A few minutes after sunset, the blue leaves the Earth and forms a belt some five degrees wide on the sky. A short time previous to this, a dark red band forms on the upper edge of the blue, but seems not to mingle with it. Its breadth is also about five degrees. As soon as the red belt appears, or a little before, a broad yellow band appears *above* the red, and seems to slightly mingle with it. The yellow band is as broad as both the others.

Of course the phenomenon is due to atmospheric refraction of sunlight. So much is certain, but what is unexplainable to me is, why the red band should be between the yellow and blue. There being but three primary colors, red, yellow and blue, and in the spectrum, as produced by refraction by a prism or grating, the colors are always in the order of their wave-lengths, red, yellow and blue, but here seems to be a case where the colors are not in the order of their wave-length, red, yellow and blue, but yellow, red and blue.

Perhaps some of your readers can throw some spectroscopic light on this question, not only as to its cause, but why is it not seen elsewhere, as well as in southern California, where a cloudy night is a curiosity? I should add that the same phenomenon is visible from the valley as I observed it a short time ago. The colors are often of almost rainbow brightness. LEWIS SWIFT.

ECHO MOUNTAIN, Cal., Oct. 13, 1898.

The New Edition of the Durchmusterung Charts.--On October 3, I wrote to the publishers of this work, Messrs. A. Marcus and E. Weber, of Bonn, Germany, requesting information concerning the progress made on it; and today I received the following communication from them, which explains itself:

ZACCHEUS DANIEL, Esq.,

Hawthorn, Pennsylvania, U. S. A.,

DEAR SIR:—We expect that the new edition of Argelander's Atlas will be ready for delivery about Easter, 1899.

The sheets 1 to 12 are already printed and 13 to 17 are ready to be printed.

We remain, Sir,

Yours very truly,

Bonn, 1898 October 15. A. MARCUS & E. WEBER.

There are forty sheets in the work, besides the preface. It is a source of much satisfaction that these charts are soon to be available, and it is hoped that they will be ready for delivery at the appointed time. ZACCHEUS DANIEL.

Hawthorn, Penn'a., 1898 October 29.

BOOK NOTICES.

Elements of Trigonometry with Tables.—This new book is by Herbert C. Whitaker, Ph. D., of the Central Manual Training School, Philadelphia, Penn. It is published by D. Anson Partridge, of same place.

The first few and the last pages are devoted to tables; natural and logarithmic values of trigonometric functions to four or five places, to convert sexigesimal into angular measure, and to convert circular into hyperbolic functions.

The five chapters of the book following are elemental, being adapted to beginners. The author has taken care from the outset to bring out well the meaning of terms and first operations in Trigonometry. It will be easy for the average student to know early what he is doing, and to come into the meaning and spirit of the new branch of study. This will also be a means of increasing interest from the first and help to maintain it after the start is made. The first chapter about the functions of angles containing nineteen pages gives the essentials needed, and illustrations of the plane curves of the sine cosine, tangent, cotangent, secant and cosecant. This is an excellent idea if the student has had enough knowledge of the use of rectangular co-ordinates to get the meaning of the curves so presented. The best algebras give this instruction. The moment a student gets the meaning of these curves he is ready to study the construction of the numerical tables of trigonometry with ease and profit. We think the author has chosen well, to give the explanation of the tables as early as the second chapter. The student is then ready for the solution of triangles in the use of both natural and logarithmic functions, in a most effective way. The geometrical device for remembering the relations of the functions of the angles in the right-angled triangle is a clear one, and it is used ingeniously. The properties of the triangle respecting altitudes, bisectors, medians and so-called incircles and ex-circles and the nine-point circle and stated and illustrated well.

Chapter VII, which treats of the spherical triangle, is especially strong in the essentials for an elementary book. The same general methods are used as in plane trigonometry. In appendix I the theory of logarithms is given quite fully with geometrical illustrations. Appendix II gives geometrical proof for the sine of the sum of two angles and derives like relations for other functions, treats the subject of goniometry, complex quantities, values of functions of multiple angles,

exponential value of $\cos\theta + i\sin\theta$, and hyperbolic functions. Following this are problems for examination without results and, finally, answers to problems of the text.

Harper's Scientific Memoirs—We are pleased to learn that the Harper Brothers, of New York, are publishing a series of scientific memoirs which give somewhat detailed information of important discoveries in science by the original workers themselves. Professor Joseph S. Ames, of Johns Hopkins University, is to edit the series and he will have associated with him in preparing the numbers of the series prominent scientists in this country and of Europe. Some of those who are to act in this capacity are as follows:

W. F. Magie, Princeton University; C. Barus, Brown University; T. C. Mendenhall, Worcester Polytechnic Institute; A. G. Webster, Clark University; H. M. Goodwin, Massachusetts Institute of Technology; H. C. Jones, Johns Hopkins University; E. P. Lewis, University of California; H. F. Reid, Johns Hopkins University; A. S. Mackenzie, Bryn Mawr College; C. L. Poor, Johns Hopkins University; C. A. Perkins, University of Tennessee; Henry Lefavour, Williams College; W. L. Robb, Trinity College; E. B. Rosa, Wesleyan University; Henry Crew, Northwestern University; D. B. Brace, University of Nebraska; F. L. O. Wadsworth, Yerkes Observatory, University of Chicago; Ira Remsen, Johns Hopkins University; E. S. Dana, Yale University; E. B. Matthews, Johns Hopkins University; and W. W. Randall, Johns Hopkins University.

These memoirs are to be illustrated with cuts and diagrams needed to show how original experiments were carried forward. The editor will make such notes, explanations and corrections to the original matter as are necessary to bring it to date. There will also be given a synopsis of the present state of knowledge pertaining to each subject treated, together with a bibliography and index at the end of each volume.

We have already had the pleasure of examining the first two volumes in this new series which have just appeared. Both of them were edited by Professor Ames. It is a privilege to say that the beginning is a very favorable one. The first volume is titled "The Free Expansion of Gases." It contains 106 pages, octavo size, neatly bound in cloth, with plain titles on the back, and admirably suited every way as a book of reference. This book contains the memoirs by Gay-Lussac, Joule, and Joule and Thompson.

Information like this from the original papers of the discoverers themselves is exactly what every true student and teacher in science wants. The retail price of this book is 75 cents.

Prismatic and Diffraction Spectra is the title of number 2 in Harper's scientific series. It contains the important papers of Fraunhofer with two folded maps of spectra at the end. These papers show the method of determining the refractive and dispersive power of different kinds of glass with reference to the perfecting of the achromatic telescope; the modification of light by the reciprocal influence and diffraction of the rays and the laws of this modification; and a short account of the results of new experiments on the laws of light, and their theory. There is also a biographical sketch of Fraunhofer, Wolleston's discovery of the fixed lines, a bibliography and an index. The price of this companion volume is 60 cents.

Lessons for Beginners in Astronomy.—Mr. C. E. Pond, of California,

is writing some very useful lessons for beginners in Astronomy and publishing the same in the *Placer County Leader*. Number four in the series on actual and apdarent distances of the heavenly bodies, appeared in the issue of the above named local paper Sept. 29. This kind of matter for the popular reading is excellent, and scores of amateurs might do the same thing and by no means exhaust the themes of Astronomy.

PUBLISHER'S NOTICES.

Contributors are asked to prepare copy carefully, and to write *all proper names very plainly*. If other language than the English is used to any considerable extent it should be type-written. Manuscript to be returned should be accompanied by postage for that purpose.

All Drawings for publication should be done in India ink, twice the size that the cut will be on the printed page. The lines, figures and letters should be made even, very smooth and uniformly black in every part of the copy, in order to secure the best reproductions possible by the modern quick processes of engraving now most generally used.

Proofs will generally be sent to authors living in the United States, if copy is furnished before the tenth of the month preceding that of publication. We greatly prefer that authors should read their own proofs, and we will faithfully see that all corrections are made in the final proofs.

Renewals.—Notices of expiration of subscription will hereafter be sent with the last number of this publication for which payment has been made. It is especially requested that subscribers fill out the blank notice sent them and promptly return it to the publisher, as this publication will not be continued beyond the time for which it has been ordered.

Messrs. Wm. Wesley & Son, 28 Essex Street, Strand, London, England, are our sole European agents.

Reprints of articles for authors, when desired, will be furnished in titled paper covers at small cost. Persons wanting reprints should always notify the publisher when the copy is sent or the proof returned. For they can not be furnished later without incurring much greater expense.

Subscription Price to Popular Astronomy in the United States, Canada and Mexico is $2.50 per volume of 10 consecutive numbers. Price per volume of 10 numbers to foreign subscribers $3.00.

All correspondence and all remittances should be sent to

WM. W. PAYNE,
Northfield, Minn., U. S. A.

GENERAL INDEX TO VOL. VI.

Aberration of parabolic mirrors, On the—J. M. Schaeberle..... 38
Administrations at the U. S. Naval Observatory, Efficiency of—(note)..... 477
Ahaz, The Sun dial of—J. Morrison..... 537
Aitken, R. G., The companion to β Orionis (= β 555)..... 586
Allegheny Observatory, The new—(note)..... 365
American association for the advancement of science, The Boston meeting, Aug. 22-27 (note)..... 185
Ames, Joseph S., Editor of Harper's Scientific Memoirs (book notices)..... 591
Andre, Search for—(note)..... 477
Andromeda nebula (note)..... 476
Aquilæ, The supposed variable star Y—H. C. circular 30, E. C. Pickering..... 418
Argelander's atlas, New edition of—(note)..... 58
Arietis observed photographically, Occultation of 26—H. C. circular, E. C. Pickering..... 110
Asteroid DQ., Gustave Ravené..... 558
Asteroids, Some facts about the—J. K Rees..... 339
Astrology, Astronomical myths—Thos. Lindsay..... 139
Astronomer's reverie, Mary E. Mitchell..... 564
Astronomers, Women, Herman S. Davis..... 129
Women (1750-1890). H S Davis..... 211, 220
"Astronomical climate" in different countries, Sidney Townley (note)..... 188
libraries (note)..... 477
myths—astrology, Thos. Lindsay..... 139
myths—the flat Earth, Thos. Lindsay..... 405
Astronomy, by Agnes Clerk (book notice)..... 190
current—W. W. Payne..... 395
for beginners, A new—(book notice)..... 63
in education, The place and function of—H. A. Howe..... 369
in newspapers, R. M. McCreary..... 103
in Southern California, Lewis Swift..... 516
of Shakespeare, Orrin E. Harmon..... 232, 263, 321
Outline for the history of—Herman S. Davis..... 455
Recent progress of—W. W. Payne..... 313
The development of photography in—E. E. Barnard..... 425
Young's revised General—W. W. Payne..... 461
Astrophysical observatory at Potsdam (note)..... 366
"Atlas der Himmelskunde" (note)..... 414
Atmospheric conditions in the central and eastern parts of United States compared with the high plateaus of the southwest, T J. J. See..... 65
Aurora, Photographic spectrum of—H. C. circular 28, E. C. Pickering..... 308
Bardwell, Elizabeth M., Observations of the Leonid meteors of Nov. 1898, at South Hadley, Mass..... 573
Barnard, E. E., The development of photography in astronomy..... 425
James E. Keeler appointed director of Lick Obrervatory (note)..... 121

β Lyræ, The System of—(note) 117
The light changes of—G. W. Myers 268
β 395=82 Ceti, Orbit of the new binary—(note) 59
Bliss, Gilbert A., Motion of a heavenly body in a resisting medium 20
Bond & Son, Chronometer makers, historical note 423
Book notice, The concise knowledge library, astronomy by Agnes Clerke 190
A new astronomy for beginners, by D. P. Todd 63
notice Hall's Differential and Integral Calculus 367
notices for December 590
Brainard, A. E., Meteors seen at Brainard Observatory (note) 418
Brashear, J. A., has a large contract to make telescopes for the U. S. Navy 121
The manufacture of glass for optical uses 104
Brooks, Wm. R., Degree of doctor of science (note) 476
The discovery of comet *i* 1898 (Brooks) 534
Brown, Miss E., Report of observations of the Sun 1896 422
Calculus, differential and integral by W. S. Hall (book notice) 367
Celestial Mechanics, Lectures by G. W. Hill (note) 476
Ceti = β 395, Orbit of the new binary 82—(note) 59
ο (Mira) Observations of the maximum of—for 1898, Rose O'Halloran 586
Chandler, S. C., Note on a practical problem for beginners in cometary computations 459
On the latest advances in knowledge of the motion of the Pole 509
Coast survey catalogue, J. F. H. (note) 587
Comet *a* 1898 Re-discovery of Winnecke's periodic—(note) 57
Winnecke's periodic, Ephemeris of—by C. Hillebrand 251
b 1898 (Perrine), Discovery of—C. D. Perrine (note) 120
Description, observations, orbit and ephemeris of— 119
Elements and ephemeris for April and May, C. D. Perrine 181
Elliptical elements and ephemeris by Perrine 248
Ephemeris of—for September 414
resemblance to comets of 1684 and 1785 I, C. D. Perrine (note) 249
Winther's ephemeris for August 355
c 1898 (Coddington), newly discovered photographically:—Elements and ephemeris by Hussey and Coddington 305
(Coddington-Pauly), Elements and ephemeris of—by Perrine 356
Ephemeris of—for July, August and Sept. 356
(note) Z. Daniel 358
d 1898 Encke, Re-discovery and ephemeris of— 304
Encke's periodic, Elements and ephemeris of—by A. Iwanow for June 250
Encke, too far south for observation at Northfield (note) 358
e 1898 (Perrine), Elements and ephemeris of—by Perrine and Aitken 306
f 1898 Wolf, Ephemeris of—for December 584
Re-discovery of—(note) 305
Wolf, Elements of—for September 415
Ephemeris for August 358
(1898), Ephemeris for October, November 534
periodic, elements and ephemeris of same for June and July by Dr. Thraem 250

g 1898 (Giacobini), discovery, observations and elements..... 357
Elements of—for September..... 415
(note)..... 306
h 1898 (Perrine), discovery by Perrine (note)..... 474
Elements and ephemeris for September, by Perrine and Aitken..... 475
Parabolic orbit, ephemeris for October and November and full description of—C. D. Perrine..... 513
i 1898 (Brooks), Discovery of—Wm. R. Brooks (note)..... 534
Elements and ephemeris by Hussey..... 533
for October and November.... 533
The orbit of—W. J. Hussey..... 556
j 1898 (Chase) discovered photographically by Chase..... 583
Elements and ephemeris of—for December by Coddington and Palmer..... 583
Photographs of—by H. C. Wilson (note)..... 583
1846 VI, H. P. Tuttle..... 561
1862 II, G. W. Hough (note)..... 585
III, Discoverer of—Lewis Swift (note)..... 417
The real discoverer, H. P. Tuttle (note)..... 535
Who discovered—Lewis Swift..... 562
1898 I (Perrine), Ephemeris for October and November..... 475
families and the constitution of comets, W. W. Payne..... 134
notes for March, H. C. Wilson, 56, April, 119, May, 181, June, 248, July, 304, August, 355, September, 414, October, 474, November, 533, December..... 583
Tempel (1867 II), search ephemeris for July..... 306
orbit, Graphical representation of—Geo. C. Comstock..... 465
(Pons-Brooks 1884 I), Comparison of elements with comet *e* 1898 (Perrine), (note)..... 357
Tempel's (1867 II), Search ephemeris for June, by R. Gautier..... 252
(Tuttle-Schulhof) 1858 III, The lost periodic—H. P. Tuttle..... 6
Cometary computations, Note on a practical problem for beginners in—S. C. Chandler..... 459
Comets and comet families, W. W. Payne, I; II, 70, III, 134, IV..... 228
of Tuttle, W. T. Lynn (note)..... 186
Computations, Note on a practical problem for beginners in cometary—S. C. Chandler..... 459
Comstock, Geo. C., Graphical representation of a comet's orbit..... 465
Conference of astronomers and physicists at Cambridge, Mass. (note)..... 416
next meeting at Harvard college (note)..... 307
Constants by the U. S. coast and geodetic survey, Determination of physical—E. D. Preston..... 101
Crookes, William, Recent advances in physical science..... 493
Crusinberry, W. A., Observations of the Leonid meteors, Nov. 1898, at Des Moines, Ia..... 575
Cygni (7085), RT, Minimum magnitude of—(note)..... 473
SS—(notes)..... 304, 413, 532
Observations of—for Sept. 1898, D. Flanery..... 587
ST—(7379) (note)..... 304
Y—(notes)..... 354, 412, 531, 581

Daniel, Zaccheus, Comet *c*, 1898 (Coddington-Pauly) (note) 359
Suggestions to observers of variable stars (note) 118
The August minimum of U Geminorum (note) 303
The new Durchmusterung charts (note) 590
Davis, Herman S., Observations of the Leonid meteors, Nov. 1898 at N. Y. City 571
Outline of the history of astronomy 455
Some remarks regarding the parallaxes of 61^1 and 61^2 Cygni, and the probable physical connection of these two stars 487
Women astronomers 129
Women astronomers (1750-1890) 211
Women astronomers (contemporary) 220
Definition and intensity of a star's image in the field of view of a parabolic reflecting telescope, J. M. Schaeberle 33
Director of Lick Observatory, James E. Keeler appointed (note) 121
Discoverer of Comet 1862 III, Lewis Swift (note) 417
Donaghe, Harriet R., Photographic flashes from Harvard Observatory 481
Double star orbit, A new graphical method of determining the elements of *a*, H. N. Russell 149
stars discovered at the Lowell Observatory catalogue of 500 new (note) 189
Douglass, A. E., Scales of seeing 193
Dunér and Scheiner on stellar evolution, translated by J. A. Parkhurst 85
Durchmusterung charts, New edition of (note) 53
The new—Zaccheus Daniel (note) 590
New—(note) 476
The northern; report of committee on same. E. C. Pickering, J. G. Hagen and M. B. Snyder, committee 125
Earth, The flat—astronomical myths, Thos. Lindsay 405
Eclipse expedition from Lick Observatory to India 231
of the Moon, A total—Dec 27 580
of the Sun in India Jan. 22, 1898 (notes) 121
Dec. 13, 1898, A partial— 580
work, The spectroscope in, E. W. Maunder 376
Ephemerides of satellites, J. Morrison 165
Ephemeris of Saturn's rings—astronomical phenomena, J. Morrison 389
Errata 128, 424, 536
Families, Comets and comet—W. W. Payne 1
Flanery, D, Observations of SS Cygni for Sept. 587
Flower Observatory, The Brashear 18-inch telescope of—(note) 588
Free expansion of gases Harper's scientific memoirs by Joseph S. Ames (book notice) 581
Gegenschein and zodiacal light (note) 366
General notes for March, 57; April, 121; May, 185; June, 252; July, 307; August, 359; September, 416; October, 476; November, 534, December 585
Glass for optical uses, The manufacture of, J. A. Brashear 104
Graphical computation of the occultations of star clusters, On a construction for the—Wm. E. Sperra 76
method of determining the elements of a double star orbit, A new—H. N. Russell 149

representation of a comet's orbit, Geo. C. Comstock..... 465
solution of *u* by curve of sines (note)..... 361
Gravitation, On Newton's law of—H. Seeliger..... 40
Growth of worlds II, W. W. Payne..... 401
Hadden, David E , Large Sunspot (note)..... 479
Observations of the Leonid meteors (1898)..... 568
Nov. 1898, at Alta, Ia. 575
Occultation of the Pleiades, Jan. 30 (note)..... 51
Omicron Ceti (Mira) (note)..... 55
The Leonid display, November, 1897 (note)..... 51
Hall, Asaph, Note on the planet DQ 567
Harmon, Orrin E., The astronomy of Shakespeare.....232, 263, 321
Heat of the Sun, Anne S. Young..... 145
Heavenly body in a resisting medium, motion of a, Gilbert A. Bliss..... 20
bodies, Perturbations of the—F. R. Moulton..... 88
Hemmelskunde, Atlas der—(note)..... 414
Herculis, RV—(note)..... 304
(6100)—(note) 354
Z, Observation of minima of same (note)..... 247
Hill, G. W., Lectures on celestial mechanics at Columbia college (note)..... 476
History of astronomy, Outline of the development of—Herman S. Davis..... 455
Hough, G. W., Comet 1862 II (note)..... 585
Howe, H. A., The place and function of astronomy in education..... 369
Hussey, W. J., Orbit of Comet 1 1898 (Brooks)..... 556
Hydrae, V, and 277 in Birmingham's Catalogue, two crimson stars, Rose O'Halloran—(note)..... 254
Hyperspace, The philosophy of—Simon Newcomb..... 380
Philosophy of—(note)..... 416
Image of a star in the field of view of a parabolic reflecting telescope, On the definition and intensity of the—J. M. Schaeberle..... 33
Jupiter 1896 7, Report of W. R. Waugh 421
Jupiter's satellites, Phenomena of—for April, 114; May, 180; June, 243; July, 302
visible to the naked eye, T. J. J. See..... 257
Keeler, James E , Appointed director of Lick Observatory (note)..... 121
Director of Lick Observatory, short article from *N. Y. Tribune*..... 186
Lantern slides for high schools (note)..... 252
Landis, W. W., Observations of the Leonid meteors, Nov 1898, at Carlisle, Pa. 574
Large refractors in the world, a table of—..... 310
Law of gravitation, On Newton's—H. Seeliger..... 40
Leland, O. M., Brilliant meteor (note)..... 536
Leonid meteor shower (1898), H. C. Wilson..... 568
meteors observed, W. W. Payne..... 568
at Alta, Ia., D. E. Hadden 568
of 1898, C. D. Perrine.. 553
of Nov. 14, 1898, observed at Philadelphia, H. R. Smith..... 571
November, 1898, observed at N. Y. City, Herman S. Davis.. 571
November, 1898, observed at Hanover, Ind., Glenn Culbertson..... 572
November, 1898, observed at Marengo, Ill., J. A. Parkhurst 573
November, 1898, observed at South Hadley, Mass., Elizabeth M. Bardwell..... 573

November, 1898, observed at Columbia, Mo., Milton Updegraff 574
November, 1898, observed at Carlisle, Pa., W. W. Landis... 574
November, 1898, observed at Alta, Ia., David E. Hadden... 575
November, 1898, observed at Barre Center, N. Y., Weston Wetherbee 575
November, 1898, observed at Des Moines, Ia., W. A. Crusenberry 575
November, 1898, observed at Minneapolis, Minn., F. P. Leavenworth 577
Leonids, Nov. 1897, David E. Hadden (note)..... 51
Rose O'Halloran (note)..... 51
of November, H. C. Wilson..... 502
Lick Observatory eclipse expedition..... 231
James E. Keeler appointed director (note)..... 121
Resignation of J. W. Schaeberle (note)..... 254
Life in other worlds, Edwin C. Mason..... 520
Light changes of β Lyræ, G. W. Myers..... 268
fluctuations of variables as related to changes in positions of periastron and in orbital eccentricity, G. W. Myers 7
Lindsay, Thos., Astronomical myths, Astrology..... 139
the flat Earth..... 405
Occulation phenomena..... 524
Lowe Observatory, List of No. 6 of nebulæ discovered at the—Lewis Swift..... 18
List No. 7..... 19
Lowell Observatory, Catalogue of 500 new double stars discovered at the—by Dr. See..... 189
Lyncis S (2376) (note)..... 354
Lynn, W. T., Tuttles comets (note)..... 186
Lyrae S (note)..... 412
Lyrae V (6871) (note)..... 354
Magnitudes of variables, photographic (note)..... 582
Manufacture of glass for optical uses, J. A. Brashear..... 104
Mason, Edwin C., Life in other worlds..... 520
Maunder, E. W., The spectroscope in eclipse work 376
McCreary, R. M., A daylight meteor (note)..... 310
Newspaper astronomy 103
Very like prophecy by Dr. Dick about photography (note). 423
Metargon and neon as new elements..... 345
Meteoric shower of November, 1898, The great—H. C. Wilson..... 502
of Nov. 13, 1897, Wm. H. Pickering.....294, 326
Meteor, A large—W. Wetherbee..... 365
Brilliant—O. M. Leland (note)..... 536
(note), Weston Wetherbee..... 586
in daylight, R. W. McCreary (note)..... 310
Shower, 1898, The Leonid—H. C. Wilson..... 568
Meteors for November, H. C. circular 31, E. C. Pickering..... 309
seen at Brainard Observatory, A. E. Brainard (note)..... 418
of 1898, The Leonid—C. D. Perrine..... 553
Milky Way, Observations of—on Pannekoek's plan (note)..... 58
Minor planets, Some facts about the—J. K. Rees..... 339

Mira (*o* Ceti) (notes)....354, 532
Light curve (note).... 413
David E. Hadden (note).... 55
Mirrors, On the aberration of parabolic—J. M. Schaeberle.... 38
Mitchell, Mary E., An astronomer's reverie.... 564
Moon, A total eclipse of, Dec. 27, 1898.... 580
Moon phases for March, 51; April, 114; May, 181; June, 243; July, 302; August, 351; September, 410; October, 470; Nov., 528; Dec.... 580
The gender of—in different languages (note).... 312
Morrison, J., Ephemerides of satellites.... 165
Ephemeris of Saturn's rings—astronomical phenomena.... 389
The Sun-Dial of Ahaz.... 537
Motion of a heavenly body in a visiting medium, Gilbert A. Bliss.... 20
of the Pole, On the latest advances in the knowledge of the—S. C. Chandler.... 509
Moulton, F. R., Perturbations of the heavenly bodies.... 88
Mary Etta, Total solar eclipse in India, Jan. 22, 1898 (note).... 123
Myers, G. W., Description of the astronomical Observatory of the University of Illinois.... 319
Light fluctuations of variables as related to changes in positions of periastron and in orbital eccentricity.... 7
The light changes of β Lyræ.... 268
Names of persons who attended conference of astronomers at Harvard college Observatory, August, 1898 (note).... 535
Naval Observatory (U. S.), Efficiency of administration at the—(note).... 477
Nebulæ discovered at the Lowe Observatory, Lewis Swift, List No. 6, 18; No. 7, 19
Neon and metargon as new elements.... 345
Neptune's satellite, Measures of—E. E. Barnard (note).... 255
Newcomb, Simon, The philosophy of hyperspace.... 380
New planet (*DQ*), Gustave Ravené.... 558
Nichols, Thos. P., Publisher (note).... 424
Observatories at Bamberg, Munich, Potsdam, Utrecht and Vienna doing variable star work (note).... 473
Observatory at the University of California (note).... 479
of the Univerity of Illinois, G. W. Myers.... 319
Description of the Charles Smith Scott—(note).... 128
Occultation of the Pleiades, Jan. 30, David E. Hadden (note).... 51
of 26 Arietes observed photographically, H. C. circular 26, E. C. Pickering.... 110
phenomena, Thos. Lindsay.... 524
Occultations of star clusters, On a construction for the graphical computation of the—Wm. E. Sperra.... 76
visible at Washington for March, 52; April, 114; May, 181; June, 243; July, 302; August, 351; September, 410; October, 470; November, 529; December.... 580
o Ceti, Observations of—Rose O'Halloran.... 255
(Mira), Observations of—Rose O'Halloran (note).... 56
region, Chart of the—(note).... 126
Spectrum of—(note).... 252
See also Mira.

O'Halloran, Rose, A few facts about the sun-spot of Dec. 6, 1897 (note)..... 50
The Leonids, November, 1897 (note)..... 51
Observations of Mira (*o* Ceti) in 1897 (note)..... 56
Observations of *o* Ceti..... 255
Observations of the maximum of Mira (*o* Ceti) 1898..... 586
The sun-spot minimum (note)..... 478
V Hydræ and 277 in Birmingham's catalogue, two crimson stars (note)..... 254
Orbit (definitive) of comet 1892 II by Dr. Steiner (note)..... 56
Origin of the Universe, Article by Dr. See (note)..... 192
Orionis, β (= β 555), The companion to—R. G. Aitken..... 585
Parabolic mirrors, On the aberration of—J. M. Schaeberle..... 38
reflecting telescope, On the definition and intensity of a star's image in the field of view of a—J. M. Schaeberle..... 33
Parallaxes of 61^1 and 61^2 Cygni, and the probable connection of these two stars, Herman S. Davis..... 487
Parkhurst, J. A., Dunér and Scheiner on stellar evolution, as translated from the German by—..... 85
Observations of the Leonid meteors Nov. 1898, at Marengo, Ill..... 573
Variable stars for April, 52; May and June, 116; June and July, 186; July and August, 246; August and September, 302; September and October, 353; October and November, 412; November and December, 472; December..... 531
The variable star SS Cygni..... 156
Variable star of shortest known period..... 55
Payne, W. W., Comets and comet families..... 1, 70, 134, 228
Current astronomy..... 395
Observations of the Leonid meteors (1898) at Northfield, Minn 568
The growth of worlds..... 346, 401
Young's revised General astronomy..... 461
Periodic Comet (Tuttle-Schulhof) III, 1858, The lost—H. P. Tuttle..... 6
Comet *b*, 1898, and its resemblance to the comets of 1684 and 1785 I..... 250
Perrine, C. D., Comet *b*, 1898, (Perrine), orbit, ephemeris for October and November and full description of comet..... 513
Discovery of Comet *b*, 1898, (Perrine) (note)..... 120
Elements and ephemeris of Comet *b*, 1898, (Perrine) for April and May..... 182
The Leonid meteors of 1898..... 553
Perturbations of the heavenly bodies F. R. Moulton..... 88
Phenomenon yet unexplained, Lewis Swift (note)..... 588
Photographic flashes from Harvard Observatory, Harriet R. Donaghe..... 481
magnitudes circular 22, E. C. Pickering..... 59
Photography in astronomy, The development of—E. E. Barnard..... 425
Prophecy of Dr. Dick concerning—R. H. McCreary (note)..... 422
Physical science, Recent advances in—William Crookes..... 493
Pickering, E. C., Comparison stars for variables. H. C. circular 27..... 125
Occultation of 26 Arietis observed photographically. H. C. circular 26..... 110
Photographic magnitudes. H. C. Circular 22..... 59
Photographic spectrum of the Aurora. H. C. circular 28..... 309

Pickering, E. C., Polarizing photometers. H. C. circular 25..... 60
Stars having peculiar spectra. H. C. circular 32..... 365
The variable star *U* Pegasi..... 29
The supposed variable star, γ Aquilæ, H. C. circular 30..... 420
Variable star clusters..... 15
The November meteors, H. C. circular 31..... 310
Witt's planet *DQ*, H. C. circular 34..... 530
Variable stars of short period, H. C. circular 29..... 262
Variable stars in clusters, H. C. circular 33..... 505
Pickering, Wm. H., Meteoric shower of Nov. 13, 1897.....294, 326
Planet notes for March, 49; April, 112; May, 178; June, 241; July, 298; August, 350; September, 408; October, 468; November 528, December 578
DQ, Asaph Hall..... 567
Gustave Ravené..... 558
Planet 1898, *DQ*, ephemeris for November, 531, December..... 584
H. C. circular 34. E. C. Pickering..... 530
ephemeris for September..... 470
elements of orbit and ephemeris..... 470
Pleiades, Occultation of January 30, David E. Hadden (note)..... 51
Pole, On the latest advances in knowledge of the motion of the—S. C. Chandler..... 509
Polarizing photometers, H. C. circular 25, E. C. Pickering..... 60
Porter, J. G., The proper motion of certain stars as a criterion of their distances..... 549
Preston, E. D., Determination of physical constants by the U. S. Coast and Geodetic survey..... 101
Prismatic diffraction spectra, Harper's scientific memoirs by Joseph S. Ames (book notice)..... 591
Proctor, Mary, Stories of starland (book notice)..... 368
Proper motion of certain stars as a criterion of their distances, J. G. Porter.. 549
Prophecy of Dr. Dick concerning celestial photography, R. M. McCreary (note)..... 422
Publisher's notices for March, 64; April, 128; May, 192; June, 256; July, 312; September, 424; October, 481, December..... 592
Ravené, Gustave, The new planet (*DQ*)..... 558
Recent advances in physical science, William Crookes..... 493
Rees, J. K., Some facts about minor planets..... 339
Reflecting telescope, On the definition and intensity of a star's image in the field of view of a parabolic—J. M. Schaeberle..... 33
Refractors, A table of large ones in the world.....310, 420
Resignation of President Kellogg of the University of California (note)..... 588
Resisting medium, Motion of a heavenly body in a—Gilbert A. Bliss..... 20
Roentgen rays, Visibility of—(note)..... 422
Royal Observatory at Greenwich, Report of—(note)..... 308
Russell, H. N., A new graphical method of determining the elements of a double star orbit..... 149
Satellites, Ephemerides of—J. Morrison..... 165
of Jupiter visible to the naked eye, T. J. J. See..... 257
Saturn's rings, Ephemeris of—astronomical phenomena, J. Morrison..... 389
satellites for June, 245; (tables) June and July, 300; August, 352; September..... 411
Scales of seeing, A. E. Douglass..... 193

Schaeberle, J. M., On the definition and intensity of a star's image in the field of a view of a parabolic reflecting telescope..... 33
On the aberration of parabolic mirrors..... 38
Resignation from Lick Observatory, 185; (note)..... 254
Schiner and Dunér on stellar evolution, translated by J. A. Parkhurst..... 85
(Schulhof-Tuttle) 1858, III, The lost periodic comet—H. P. Tuttle..... 6
Scorpii (5830), R--(note)..... 354
Second Moon to Earth (note)..... 253
See, T. J. J., Comparison of the atmospheric conditions of the central and eastern portions of the United States with those in the high plateaus in the southwest..... 65
Jupiter's satellites visible to the naked eye..... 257
The ages of stars (letter)..... 361
Seeliger, H., On Newton's law of gravitation..... 40
Seeing, Scales of—A. E. Douglass..... 193
Shakespeare, The astronomy of—Orrin E. Harmon..... 232, 263, 321
Smith, H. R., Observations of the Leonid meteors of Nov. 1898, at Philadelphia..... 571
Space, Transcendental—paper by Chas. H. Chandler (note)..... 312
Spectroscope in eclipse work, E. W. Maunder..... 376
Sperra, Wm. E., On a construction for the graphical computation of the occultation of star clusters..... 76
Solar eclipse at Buxar, India, Jan. 22, 1898 (note)..... 123
in India, Jan. 22, 1898 Etta Moulton (note)..... 121
of Jan. 22, 1898 Photograph of the total—(note)..... 185
observed at different places in India Jan. 22, 1898 (note)..... 124
Stahn, Justice (note)..... 480
Star, A new "runaway"--Cordoba zone catalogue $5^h.243$..... 61
catalogue, Coast Survey, J. F. H. (note)..... 587
clusters, On a construction for the graphical computation of the occultations of—Wm. E. Sperra..... 76
Variable—E. C. Pickering..... 15
7792 SS Cygni, The variable—J. A. Parkhurst..... 156
Stars, A catalogue of the magnitudes of 1081—by Stanley Williams..... 312
and Milky Way, from Miss Byrd's laboratory methods in elementary astronomy..... 288
as a criterion of their distance, The proper motion of certain—J. G. Porter..... 549
having peculiar spectra, H. C. circular 32, E. C. Pickering..... 363
image in the field of view of a parabolic reflecting telescope, On the definition and intensity of a—J. M. Schaeberle..... 33
61^1 and 62^2 Cygni and the probable physical connection between them, The parallaxes of—Herman S. Davis..... 487
The ages of the—T. J. J. See (letter)..... 361
Stellar evolution by Dunér and Schiner, translated by J. A. Parkhurst..... 85
Stories of starland, Mary Proctor (book notice)..... 368
Sun, 1896, Report of—Miss E. Brown..... 422
A partial eclipse of—Dec. 13, 1898..... 580
dial of Ahaz, J. Morrison..... 537
Sun's equatorial acceleration and the sun-spot period, On the causes of the— 209
heat, Anne S. Young..... 145

Sun-spot, A few facts about the group of Dec. 6, 1897, Rose O'Halloran (note) 50
Large, David E. Hadden (note) 479
minimum, Rose O'Halloran (note) 478
period and the causes of the sun's equatorial acceleration 209
Feb. 7 and 12 (note) 50
Swasey, Ambrose, abroad (note) 365
Swift, Lewis, Astronomy in southern California 516
List No. 6 of nebulæ discovered at the Lowe Observatory, Echo Mountain, Cal. for 1900 18
List No. 7 of Nebulæ discovered at the Lowe Observatory 19
Phenomenon yet unexplained (note) 589
The Van Duzee 16-inch dialyte (note) 359
Who discovered comet 1862 III? 417, 562
Telegrams of announcement and discovery (note) 189
Telescope, at the Paris Observatory, The great—(note) 477
of Chamberlin Observatory, Focal length of—(note) 416
On the definition and intensity of a star's image in the field of view of a parabolic reflecting—J. M. Schaeberle 33
of Flower Observatory, The Brashear 18-inch (note) 588
Townley, Sidney, "Astronomical climate" in different countries (note) 189
Trigonometry by Herbert C. Whitaker (book notice) 590
Tuttle, H. P., The lost periodic comet (Tuttle-Schulhof) III, 1858 6
Comet VI, 1846 561
Who was discoverer of comet 1862 III? (note) 535
U Draconis (6899) (note) 355
U Geminorum, Next maximum in August, Zaccheus Daniel (note) 303
Maximum of 248
(2815) (note) 117
u, Graphical solution of—by curve of sines (note) 361
Ultra-Neptunian planet (note) 307
Udegraff, Milton, Observations of the Leonid Meteors, November, 1898, at Columbia, Mo 574
U Pegasi, Variable star, E. C. Pickering 29
U. S. Coast and Geodetic survey. Determination of physical constants by the—E. D. Preston 101
Vacation notes, H. C. Wilson 360
Van Duzee 16-inch dialyte, Lewis Swift, (note)
Variable in Cassiopeæ, The new—(note) 355
Gemini, Anderson's new—(note) 184
Lynx, Anderson's new—(note) 185
New Algol type (note) 581
of presumably very long period (note) 247
star, U Pegasi, E. C. Pickering 29
Anderson's new—(note) 118
Atlas, by Hagen (note) 582
clusters, E. C. Pickering 15
observers, Suggestions to—Z. Daniel 118
of shortest known period, J. A. Parkhurst (note) 55
7792 SS Cygni, J. A. Parkhurst 156
SS Cygni, Observations of for September—D. Flanery 587
work at the German Observatories (note) 473
Y Aquilæ, The supposed, H. C. circular 30, E. C. Pickering 418

Variable stars for January, 1899, J. A. Parkhurst 581
J. A. Parkhurst, for April, 52; May, 116; June, 116; June and July, 182; July, 246; August and September, 302; September and October, 353; October, 412; November and December, 472; December 531
in clusters, H. C. circular 33, E. C. Pickering 505
of short period, H. C. circular 29, E. C. Pickering 262
in recent publications (note) 414
old theory (note) 474
Variables, Two new (note) 532
as related to changes in positions of Positions of Periastron and in orbital eccentricity, Light fluctuations of—G. W. Myers 7
Comparison star for, H. C. circular 27, E. C. Pickering 125
Notation of, recently discovered 247
Photographic magnitudes of—(note) 582
Venus at Lowell Observatory, Observations on—(note) 253
Visibilty of the Rœntgen rays (note) 422
Waugh, W. R., Report on Jupiter during 1896-7 421
Wetherbee, W., A large meteor (note) 365
Brilliant meteor (note) 586
Observations of the Leonid meteors, November, 1898, at Barre Center, N. Y 575
Whitaker, Herbert C., Author of new trigonometry (book notice) 590
Williams, A. Stanley, Catalogue of the magnitudes of 1081 stars (note) 312
Wilson, H. C., Comet notes for March, 56; April, 119; May, 181; June, 248; July, 304; August, 355; September, 414; October, 474; November, 533; December 583
Photographs of the new comet *j*, 1898 (Chase) 583
Planet notes for March, 49; April, 112; May, 178; June, 241; July, 298; August, 350; September, 408; October, 468; November, 528; December 578
The great meteoric shower in November 502
The Leonid meteor shower, 1898 568
Vacation notes 360
Winnecke's comet, Ephemeris of—for March, Re-discovery of—note 57
Worlds, The growth of, W. W. Payne 346
Women astronomers, Herman S. Davis 129
(1750-1890), Herman S. Davis 211
(contemporary), Herman S. Davis 220
Young, Anne S, The Sun's heat 145
Young's revised General Astronomy, W. W. Payne 461
Zodiacal Light and Gegenschein (note) 366
(note) 307